METALLURGIA

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(INCORPORATING THE METALLURGICAL ENGINEER.)

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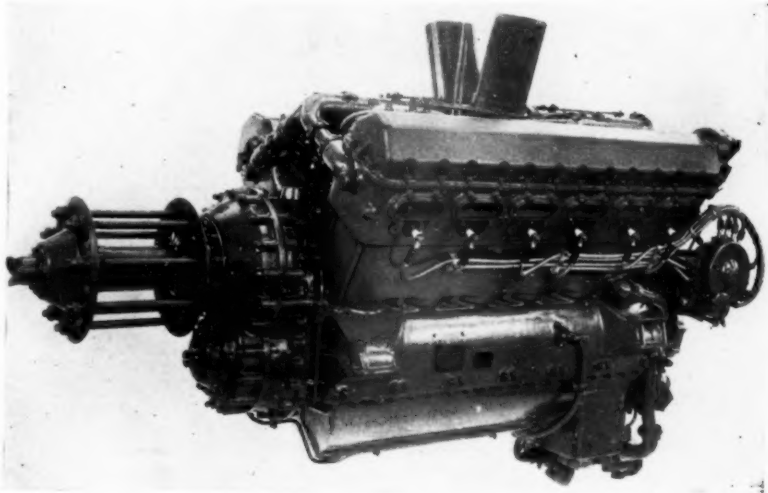
Alloy Steels for Aircraft Construction

By Dr. W. H. HATFIELD, F.R.S. (Sheffield)

The advancement of aircraft construction is due, in no small measure, to the developments in metallurgy, not the least important being those associated with the metallurgy of special steels. In this article Dr. W. H. Hatfield refers to some of these developments, and discusses the types of steel which have come to be regarded as of the utmost importance to safety and reliability.

THE science of aeronautics and the technology of the internal combustion engine have advanced side by side; and it is no exaggeration of the facts to state that neither the aircraft itself, nor the motor could have reached its present state of advancement without the developments which have taken place in the metallurgy of special steels.

The first machine to fly under its own power, built by the Wright Brothers just thirty years ago, was driven by 12 to 15 h.p. motor which weighed 240 lb., or 16 lb. per unit horse-power; whilst the machine itself weighed as much as 61 lb. per horse-power. Special alloy steels, as we know them to-day, were not then available. By 1914 the engine weight was reduced to 3½ to 4 lb. per horse-power, and during the War years, when the normal research of a decade or more was carried out in four years, engine efficiency was increased to such an extent that by 1918 the power-weight ratio of a service fighter was up to nearly ½ h.p. per pound, and the total weight of the aircraft was down to 8 lb per brake horse-power. During the post-war years engines have improved still further in efficiency, and also in reliability. Corresponding to this improvement in the engine, the application of metals, and particularly of the alloy and of stainless steels, to construction of the aircraft themselves has resulted in the production of planes which are both lighter and stronger than those built ten years ago.



By courtesy of Rolls-Royce Ltd.
A light but powerful aero-engine which has resulted from developments in the metallurgy of special steels.

During this rapid technical development the importance of safety and reliability has been pre-eminent, and under the wise guidance of the Air Ministry, the British aircraft industry to-day produces aeroplanes of the greatest efficiency and safety.

Most aircraft steels are melted in electric furnaces and full use is made of modern technology in producing sound steel as free as possible from non-metallic impurities and cast into ingots designed to give, not the greatest possible yield, but steel most free from segregation and other troubles. Careful quantitative control of forging temperatures, careful heat-treatment and exhaustive inspection at every stage of operations all combine to produce steels as near perfect as can be obtained.

Safety in Design.

A word might usefully be written concerning safety in design; and in this connection Table I., which gives data concerning the strength of various materials, may be found of interest.

The choice of material for a particular part has to take account of three factors: strength for weight, reliability and suitability for forming into the desired shape by the method to be employed. Reliability, involving as it does complete freedom from defects, is based to a large extent upon ductility and freedom from brittleness. Ductility is necessary because, during fabrication or in service, the steel is liable to suffer deformation, arising from stresses in excess of those arising in normal steady duty. But for these considerations there would be every inducement to aim directly in all cases for the highest possible hardness and tensile strength, since by such means one would expect to raise the permissible working stress and thus reduce weights.

The highest stress under service conditions should be below the true elastic limit of the material in order to avoid "permanent set." The Air Ministry has of late years wisely pursued the policy of basing the characteristics of steel supplies, to a large extent, upon the "proof stress values," corresponding to 0·1% of permanent set. Such a value is the nearest practically determinable approach which appears to be commercially possible to a true elastic limit, and although the testing methods to determine proof limits are by no means ideal, experience has now established such tests on a reasonably satisfactory basis. Thus the "proof stress" becomes the basis of the factor of safety.

Many parts of engines and aircraft are, subjected to "alternating stress." Failure might, therefore, occur by fatigue if the latter value is not taken into consideration in the factor of safety. The breakdown in a fatigue failure generally occurs without measurable deformation, and in such cases the determination of proof stress cannot be taken as a guide.

The data given in Tables I and II, show both the proof stress and the fatigue range; which do not run parallel to each other in the different types of steel. In general,

By courtesy of Thos. Firth and John Brown, Ltd.

A large electric furnace used for melting aero steels.

the higher the tensile strength, the higher becomes the ratio of proof stress to maximum stress, but at the same time the ratio of "fatigue limit" to maximum stress (for reversed stresses with mean stress zero) decreases. Thus steels of 80/100 tons per sq. in. maximum strength, with a fatigue limit ratio of say 40 to 45%, have proof stress ratios approaching 90%; whereas a steel of 30 tons per sq. in. tensile has both these ratios approximately 50%. The old method of designing to a factor of safety based on ultimate strength was unconsciously not far removed from the later principle of designing on fatigue limit, since the ratio of these quantities is not greatly changed for various steels. The strength of any part should naturally be looked at from both points of view—*i.e.*, according to the greatest applied stress and also the order of the alternating stress, which is operative, suitable factors of safety being provided for both features. It is clear, however, that for certain units, for example, vibratory and reciprocating parts subject mainly to alternating stress, the use of a steel having a high fatigue range is essential. Generally speaking, design seems to be based on stressing to two-thirds of the proof stress or one-half of the maximum stress in tension; it being understood that the calculation of the maximum imposed stress takes note of every conceivable additive abnormal or accidental factor. The author would go so far as to state that with the present reliability of the material, and the extending knowledge of its capacity for resisting permanent deformation, the factor for "ignorance" from this point of view is at a low value. A word might also be said concerning the author's frequently expressed view that the design is safer as regards many parts when the materials employed have a reasonable capacity for plastic deformation. Clever calculations based on high value may result in an adequate paper factor of safety which does not actually exist in practice. It is his opinion that adequate ductility must exist for safety in all highly stressed parts.

Since the War many new steels have been introduced into aircraft practice, and the Air Ministry has taken a foremost part in their development.

Referring back to aircraft specifications, one could count in 1917 about 35 different specifications covering a dozen types of steels. To-day Air Ministry specifications number nearly 100 covering about 30 different types of steel. Outstanding amongst these are the newer types of stainless steels about which more will be said later.

In Table II. the author has given a typical example of the analysis and mechanical properties of each of the more important aircraft steels, as well as the corresponding standard specification numbers. From this table it should be possible for the reader to appreciate the essential characteristics of each.

Carbon Steels.

There has been little change in carbon steels since 1918 except in quality and reliability. The range of carbon contents is very wide, and provides for many different purposes from the dead soft material suitable for deep pressings such as water jackets, to the high carbon steels such as are used for high tensile wire for valve springs. Cylinders made in 0·55% carbon steel demand a high standard of uniformity and cleanliness and it is usual to accept such steels on micro-examination, this ensuring a sufficiently high standard.

Medium Tensile Alloy Steels.

Increasing use is being made of steels containing about 1·5% manganese and a small percentage of molybdenum for such items as tubes and plate fittings where a medium high tensile condition is demanded. These steels are adapted for ease in welding, and in bar from (D.T.D. 188) they possess good mechanical properties. The 3% nickel steel, formerly used as a 45-ton heat-treated alloy steel, has been to some extent superseded by a slightly modified composition heat-treated to give a minimum of 55 tons per square inch tensile strength.

Low chromium-molybdenum steels are finding use as tubes of 45 tons per square inch tensile strength, whilst a higher alloy type of chromium-molybdenum steel containing a small percentage of nickel is being used as an alternative to the higher tensile alloy steels of the nickel-chromium and nickel-chromium-molybdenum types.

TABLE I.
STRENGTH-WEIGHT RATIOS OF VARIOUS MATERIALS.

	1.	2.	3.	4.	5.		
Material. (All wrought condition except.*)	Specific Gravity.	Modulus, Tons per Sq. In.	0·1% Proof Stress, Tons per Sq. In.	Maximum Stress, Tons per Sq. In.	Fatigue Limit, Tons per Sq. In.	Ratio, Proof Stress/Specific Gravity.	Ratio, Fatigue Limit/Specific Gravity.
Mild steel (2 S. 21)	7·87	13,400	15·0	32·0	±14·0	1·92	1·78
Medium carbon steel (2 S. 1)	7·86	13,300	18·0	35·0	±15·0	2·28	1·92
3½% nickel steel (S. 69)	7·87	13,050	45·0	55·0	±27·0	5·73	3·43
Special high-tensile steel (S. 65)	7·86	13,200	56·0	65·0	±30·0	7·14	3·82
Nickel-chromium case-hardening steel (S. 82)	7·87	13,100	44·0	85·0	±37·0	5·60	4·71
100-ton nickel-chromium steel (2 S. 28)	7·87	13,150	72·0	100·0	±41·0	9·26	5·22
Stainless steel (D.T.D. 46 A)	7·725	13,400	65·0	83·4	±36·0	8·42	4·66
Stainless steel (D.T.D. 168)	7·731	13,500	60·0	80·4	±35 approx.	7·75	4·53
Copper	8·90	8,000	2·6	14·0	± 3·5	0·29	0·39
Brass	8·50	8,000	5·0	20·0	± 7·5	0·59	0·88
Duralumin	2·85 mx.	4,510	12·0	25·0	±10·5	4·22	3·95
Super Duralumin	2·82	4,510	18·0	30·0	±12·5	6·38	4·43
Y alloy	2·85 mx.	4,825	12·0	22·0	±10·0	4·22	3·51
Aluminium-copper alloy	2·90	4,920	—	9·0	± 3·0	—	1·04
R.R. 56 alloy	2·85	4,920	17·0	30·0	±10·7	5·97	3·51
Magnesium alloy (Elektron)	1·82	2,800	11·5	20·0	± 8·9	6·32	4·89
Ash	0·53	630	—	3·57	—	2·25*	—
Spruce	0·40	536	—	2·50	—	2·08*	—
Oak	0·69	760	—	4·00	—	1·95*	—
Teak	0·80	1,070	—	5·40	—	2·26*	—

* Proof stress assumed to be one-third maximum stress.

High Tensile Alloy Steels.

Greater service for highly stressed structural parts such as crankshafts and connecting rods, has been made possible by the use of modifications of the usual 3½% nickel-chromium steels. These modifications have included additions of molybdenum and vanadium, and tensile

strengths up to and in excess of 70 tons per square inch with high ductility and impact value, as well as high yield ratio, are consistently obtained. It should be stated that such steels demand the highest skill of the steel-maker both in manufacture and manipulation. The same remarks apply to the alloy steels employed for still higher tensile strengths such as the air-hardening nickel-chromium steels, chromium-vanadium steel used for valve springs, and the case-hardening nickel-chromium steels.

chromium steels. It possesses slightly greater toughness than the air-hardening variety and combines a tensile strength of 85 tons per square inch minimum with 12% minimum elongation, and high notched impact value.

The 100/110-ton tensile air-hardened nickel-chromium steel combining high tensile properties with simplicity of treatment is suitable for many other parts besides gears. It is not normally case-hardened, but can be so treated if desired.

TABLE II.
STRUCTURAL STEELS.

		Typical Analysis.							Numbers of Specifications.	Treatment or Condition.	Mechanical Properties.								
		C.	Si.	Mn.	Ni.	Cr.	Va.	Mo.			Proof 0·1%, Tons per Sq. In.	Yield Point, Tons per Sq. In.	Max. Stress, Tons per Sq. In.	Elongation %.	R/A., %.	Izod, Ft./lb.	Brinell.	Fatigue, ± tons per Sq. In.	Modulus of Elasticity, Tons per Sq. In.
Carbon steels.	(1)	0·12	0·18	0·65	0·10	—	—	—	D.T.D. 41, 82; 2 T. 26; 2 S 21. (See also D.T.D. 141; 12 A; 2 S. 14.)	Normalised 900° C.	16·2	17·5	28·5	37	64·5	65	124	±13·5	13,400
										Refined W. Q. 760°C.	14·1	17·2	31·3	33	60·9	85	137	±14·0	13,400
	(2)	0·28	0·20	0·75	0·22	—	—	—	2 S. 1; S. 71. (See also 2 S. 3; D.T.D. 17 A.)	Normalised 870° C.	18·5	19·5	35·8	31·5	57.0	32	151	±14.9	13,300
	(3)	0·41	0·14	0·50	0·12	—	—	—	2 S. 6; S. 76.	Normalised 850° C.	20·8	23·9	38·9	27	53·0	28	170	±16·5	13,300
	(4)	0·55	0·23	0·58	0·16	—	—	—	S. 70; S. 79; D.T.D. 153, 5 W.3, 5 W. 8.	Normalised 830° C.	23·0	27·8	46·5	21	38·0	10	202	±19·0	13,250
									(See also D.T.D. 215; 187.)	Oil harden 830° C. Temp. 600° C.	29·5	41·0	56·0	18	55·0	12	241	±22·5	13,150
1½% manganese steel.	(5)	0·29	0·19	1·4	0·21	—	—	—	D.T.D. 126, 124; T. 35; 2 T. 1.	Normalised 850° C.	20·5	23·6	40·2	30·0	57·0	50	187	±17·5	13,300
									(See also T. 45; D.T.D. 137, T. 50, 138.)	Oil harden 850° C. Temp. 640° C.	24·0	29·1	40·5	31·0	59·0	85	187	±17·5	13,300
3% nickel case-hardening steel.	(6)	0·12	0·15	0·50	3·10	—	—	—	3 S. 15.	Refined W.Q. 760° C.	26·0	35·1	49·3	20·0	49·0	70	217	±20·5	13,050
3½% nickel steel.	(7)	0·43	0·19	0·64	3·58	0·2	—	—	S. 69.	Oil quenched 850° C. Temp. 570° C.	53·0	56·4	63·8	22·0	61·0	55	293	±27·0	13,050
5% nickel case-hardening steel.	(8)	0·12	0·14	0·30	4·9	—	—	—	2 S. 4; S. 67. (See also S. 83 A.)	Refined 840° C. W.Q. 760° C.	25·9	40·1	58·8	18·0	48·0	28	269	±26·0	13,000
3½% nickel-chromium steel.	(9)	0·31	0·14	0·70	3·4	0·70	—	—	D.T.D. 98 A; 99, 600; 3 S.11; 2 S. 2.	Oil harden 820° C. Tempered 600° C.	50·0	54·5	60·1	22·0	61·0	68	277	±26·5	13,100
Nickel-chromium case-hardening steel.	(10)	0·14	0·21	0·40	4·49	1·2	—	—	S. 82.	Refined oil Q. 760° C.	48·3	73·0	89·0	18·0	63·7	30	418	±39·0	13,100
Nickel-chromium air-hardening steel.	(11)	0·28	0·15	0·50	4·20	1·5	—	—	2 S. 28, 54 A; 282.	Air harden 820° C. Temp. 250° C.	65·2	85·0	106·0	12·5	45·0	15	495	±45·0	13,150
Nickel-chromium-molybdenum-vanadium	(12)	0·23	0·18	0·55	3·04	1·47	0·19	0·53	S. 65, S. 81.	Oil Q. 850° C. Temp. 640° C. A.C.	65·1	68·7	73·9	21·5	69·0	48	340	±32·0	13,200
Chromium-molybdenum steel.	(13)	0·32	0·13	0·55	—	0·55	—	0·25	D.T.D. 167.	Oil harden 820° C. Temp. 680° C.	36·5	45·5	53·8	24·5	67·0	65	255	±22·0	13,150
Chromium-molybdenum high-tensile steel.	(14)	0·30	0·21	0·59	0·89	0·88	—	0·94	D.T.D. 228.	Oil Q. 875° C. Temp. 640° C. A.C.	53·7	58·5	64·0	19·0	57·0	50	293	±27·0	13,150
Carbon chrome ball-bearing steel.	(15)	0·99	0·21	0·48	0·12	1·41	—	—	—	W.H. 810	—	—	—	—	—	—	650	—	13,000
Chrome-vanadium spring steel.	(16)	0·46	0·17	0·57	0·15	1·40	0·18	—	D.T.D. 4 A.	Oil Q. 850° C. Temp. 490° C.	72·0	82·5	87·0	16·0	48·0	24	402	±42·0	13,000
Silicon-manganese spring steel.	(17)	0·52	1·95	1·05	—	0·05	—	—	D.T.D. 115.	Oil harden 860° C. Temp. 480° C.	66·0	78·5	90·2	14·0	32·0	11	418	±43·0	12,500
Chrome-aluminium steel for nitriding	(18)	0·39	0·23	0·61	—	1·63	Al. 1·10	0·18	D.T.D. 87.	Oil harden 900° C. Temp 650° C.	47·6	50·2	57·5	22·5	59	50	269	±24·9	12,800

Case-hardening Steels.

For parts where a hard-wearing surface is demanded in combination with a highly stressed tough core, such as in camshafts, rockers and small gears, the carbon case-hardening steel has largely given way to case-hardened alloy steels; 2% nickel case-hardening steel has been replaced by 3% or 5% nickel, and a high tensile case-hardening nickel-chromium steel is used where a very high tensile core strength is demanded. The latter steel is very suitable in many situations where surface hardness is not required, since as a straight heat-treated steel it ranks closely in tensile strength behind the air-hardening nickel-

Nitriding Steels.

The process of surface hardening certain classes of steel by " Nitriding " has been put into commercial applications in recent years. The advantages of the method lie in the production of a superhard thin skin by a process which is free from the difficulties attending ordinary case-hardening: the risks of cracking and warping which always demand a finishing operation such as grinding for removal of the irregularities and usually entail a certain percentage of wasters are reduced. The nitriding operation, carried out at comparatively low temperatures, permits of parts being finished to exact dimensions, and except for slight cleaning

[By Courtesy of Firth-Derihon Drop Stampings Ltd.

A drop stamp used for forging aero engine parts.

up no further work is necessary after the nitriding treatment.

The base material on which this operation is carried out is generally the special aluminium-chromium steel developed for the purpose. The D.T.D. specification No. 87 covers this type of steel, and it is a useful property that it can be hardened and tempered like other alloy structural steels, giving a range of useful conditions.

Other steels are used for " nitriding " such as chromium-vanadium steel and chromium-molybdenum steel (low nickel). These latter do not give such an intensely hard skin as the aluminium-chromium steels, but this is an advantage for certain applications, since naturally the less hard skin is less liable to be " flaked " under intense local pressure.

Mention should be made of the interesting work of Mr. Sutton and his colleagues at the Royal Aircraft Factory on the nitriding of austenitic and allied steels. The nitriding of the surface is shown to be facilitated by a previous deposition of a thin layer of copper.

Valve Steels.

In the last years of the War the only special steels considered for this duty were the plain high chromium steels. As a result of much experimental work it now appears that one or other of the austenitic chromium-nickel-tungsten steels covered by specification D.T.D. 49A, offers the best range of usefulness. Certain of these steels, in addition to their heat-resisting properties, have also the advantage that they can be surface-hardened on the wearing parts by the nitriding operation mentioned above. The valve question is still very much alive, and it cannot be said that the problem has yet reached a final solution. The high coefficient of thermal expansion of most of the austenitic steels necessitating large clearances, and the comparatively low thermal conductivity, are disadvantages of such steels.

High Thermal Expansion Steels.

There are a number of items in engine construction where steel is required to work in conjunction with light alloys, for example, cylinder head bolts and studs, valve seatings and cylinder liners the steel providing strength or abrasion resistance whilst the adjacent light alloy avoids the inclusion of undue weight. The comparatively high thermal expansivity of the aluminium leads to looseness or difficulties in fitting unless the steel unit operating in conjunction with it has a very similar rate of thermal expansion. A type of steel which had been developed in another connection has been found to fulfil these requirements. This steel is an austenitic nickel-manganese-chromium steel, which combines a thermal expansion of 0·000021 per 1° C. up to 400 or 500° C., with good mechanical properties and resistance to abrasion. It is somewhat tough as regards machining, but this does not appear to be a special difficulty.

Stainless Steels.

The characteristic features of the various types of stainless steels are now fairly well appreciated. The low carbon and medium carbon 14% chromium steels are capable of being hardened and tempered The lower carbon type, more usually known as stainless iron, naturally hardens much less intensely than the 0·30% carbon steel, and is more frequently employed in a fairly soft and malleable condition. The quality of steel which has been adapted to meet the specification D.T.D. 46A, is really intermediate between the two types mentioned, having a carbon content of the order of 0·18%. In the form of thin strip this material has air-hardening properties permitting the attainment of a little over 80 tons per square inch tensile strength, and if the air-hardening is followed by a very light tempering a substantial ductility is obtained.

High chromium steels with a sufficiently low carbon content are " ferritic," and are non-hardening when quenched from a high temperature. The 18% chromium irons which come in this class have a tendency to brittleness, but by the inclusion of a moderate percentage of nickel—normally about 2% with a carbon content in the region of 0·1%—they are again in the martensitic or hardening class of steel. Specification S.80 is based on this type of steel, and with minor modifications the same steel meets a number of other specifications for sheet and bar—*e.g.*, D.T.D. 146, D.T.D. 168 (high tensile) and D.T.D. 225. The high chromium high nickel steels are based on the 18/8 composition austenitic and non-hardening and demand a different technique, the chief characteristics of which are softening by high temperature treatment and hardening by cold working.

The corrosion-resisting properties of the three types of steels show definite differences, the higher chromium conferring increased resistance, and the extra nickel making the resistance more general over a wider range of media. The 18/2 (18 chromium / 2 nickel) type of steel is practically resistant to sea water, whilst the 18/8 (18 chromium / 8 nickel) type is completely resistant as long as the surfaces are kept reasonably free from deposits. The steels can be formed to all manner of shapes, and it is now possible to weld them without impairing their corrosion-resistance or mechanical strength. The temporary difficulty due to " weld decay " effects has been for some time completely overcome, although the troubles which arose in this connection have left their landmark in the Air Ministry specifications in the form of the special corrosion test or disintegration test employing an acid copper sulphate test reagent, the introduction of which was the result of researches in the Brown-Firth Research Laboratories in Sheffield in 1927. The further question of contact corrosion has also been brought to a fairly satisfactory stage.

The stainless steels now available range from below 30 tons to above 100 tons per square inch tensile strength, and are obtainable in almost any form or size.

It will be seen, therefore, that metallurgical science has placed at the disposal of the aircraft designer many types of steel possessing widely varying properties. His task, however, is never finished; for no sooner is one problem satisfactorily solved, than others are presented for solution. Nevertheless, the aircraft industry may take some satisfaction from the thought that they have at their disposal to-day steels possessing properties undreamt of not so many years ago, produced to the very highest standard of quality.

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Aircraft Construction and Metallurgy.

STIMULATED greatly by the war, commercial aviation has made remarkable progress. It came into being at a stage of the world's history when there were immense and urgent tasks of reconstruction, when the factor of increased speed was gradually being appreciated, and to-day the achievements of yesterday have become almost a commonplace, in view of the regularity at which service conditions can now be maintained.

The experience of a century of transportation is behind these achievements in the air, and the lessons of the past appear to have been applied with profit to the development of commercial aeronautics. So great is the development in aeroplane construction that Sir Philip Sasoon has promised a fighting plane before the end of the year capable of 300 m.p.h. But speed is sought in all classes of aircraft, and many responsible British firms have fast civil aeroplanes in course of construction in response to the Air Ministry's offer of a prize of £25,000 for an efficient, economical air-liner of medium size.

On the grounds of both speed and economy the designer must take advantage of any developments in materials which are applicable for constructional purposes and in no section has greater progress been made than in metals and alloys. Indeed, it would be safe to say, that the progress of the aeroplane to its present high standard is due to metallurgical discoveries and developments during the last 20 years. During this period there has been substantial new achievements and entirely new steels are now employed in the aircraft industry ; but great progress has also been made in other directions. The physical chemistry and general conditions of steel making are more completely understood, and cleaner steel is now made ; steel freer from non-metallic impurities and in consequence much more reliable in service. Again hot working is now performed in the optimum range of temperature, when the steel best lends itself to such deformation. In the field of heat-treatment also great knowledge has been obtained as the result of researches by many investigators at home and abroad. Inspection is extremely meticulous. It is realised that the smallest irregularity or defect may be the predisposing cause of failure in the finished part. The net result is a very high standard in the production of aeroplane parts required to be in steel. The application of steel to different parts in aircraft construction are discussed in this issue by Dr. Hatfield and the mechanical properties of selected types are given.

In aircraft construction, probably the most important issue from a metallurgical point of view is the production of metals and alloys possessing a high weight-strength ratio combined with sufficient ductility to permit forming operations being carried out with reasonable ease. Other desirable properties are low-specific gravity, permitting greater mass for the same weight ; high resistance to corrosion, and freedom from complicated and expensive heat-treatment requirements. The light alloys of aluminium and magnesium appear to offer the most promising field for this class of work ; indeed the rapid development of aluminium and magnesium alloys during recent years is one of the outstanding features of metallurgical progress.

For many years aluminium alloys have been used as standard practice in aircraft construction. Suitable alloys have been developed which have proved thoroughly reliable for withstanding stress, fatigue, corrosion and all other factors expected in a structural material, such as in the delicate, complicated girderwork of a rigid airship, the less intricate but equally important structure forming the fuselage and wings of an aeroplane, or many parts of the engine subjected to varying ranges of temperature. The importance of the stress-weight ratio delegates to a secondary position those questions of comparative cost which are so important in general engineering. The ability of aluminium alloys to resist fatigue is a factor which is of vital importance to the designer and it is now possible to fix a range of alternating stress which the metal can withstand indefinitely without failure. Some data on the physical properties of aluminium alloys by Mr. J. T. Robinson and published in this issue confirm this statement and show to what extent the properties of these alloys have been developed.

Developments, during recent years, with magnesium alloys have shown that they present very attractive features. The ratio of strength to weight, which is naturally high owing to the low density of magnesium itself, has shown a steady tendency to rise as a result if the production of stronger alloys. In certain types of castings this ratio is higher than can as yet be attained in aluminium alloys ; in wrought material, on the other hand, if account be taken of ductility, heat-treated alloy steels and aluminium alloys still hold a considerable lead, but the article on magnesium alloys in this issue by Mr. Player will be read with interest.

The technique of working both aluminium and magnesium alloys has been developed to a high degree, but the question of corrodibility is a serious problem. Great progress has been made in this direction, particularly with aluminium alloys, for which the anodic oxidation process is gradually finding widespread adoption. In the near future some such process may be developed for magnesium alloys. Magnesium, unlike aluminium, does not automatically become coated with a chemically inert film of oxide—a film which is only necessary to strengthen to secure excellent protection. The protection of magnesium alloys against corrosion is thus a much more difficult problem and, although these alloys are being increasingly used in aircraft construction, a considerable impetus will be given to their application when this problem is overcome to an extent comparable with aluminium alloys. The early history of nearly every metal or alloy having specially valuable properties is a story of how difficulties in production are overcome and how properties are improved and in the very near future developments may be expected which will improve the possibilities of these alloys for aircraft work.

The future conquests of aeronautics are bound up with development in metals and alloys. Commercial aeronautics which is essentially a world movement, must therefore, be developed on broad lines. To the British Empire its development, with all it implies, is a task of very great importance, as no nation will derive more from its encouragement, not only in regard to trade possibilities but in demolishing barriers resulting from infrequent communications. The designer and the metallurgist must therefore, co-operate to achieve the success so desirable.

Trade of the United States with the British Empire.

WHILE it has long been a matter of common knowledge that the value of exports from the United States exceeds that of imports by substantial proportions, and that this situation is reversed in Great Britain, it is by no means equally well known that the great bulk of the excess exports of the United States constitutes the major portion of the import surplus of Great Britain. Since 1926 the United States has exported commodities to an average annual value of $561 million more than the value of her commodity imports. In those same years the average annual excess of exports over imports in the United States trade with the British Empire has amounted to $495 million, and that in her trade with Great Britain alone to $395 million.

Trade of the United States with Great Britain and the British Empire.
(Millions of dollars.)

	1926.			1927.			1928.			1929.			1930.		
	Ex.	Im.	Bal.	Ex.	Im.	Bal.	Ex.	Im.	Bal.	Ex.	Im.	Bal.	Ex.	Im.	Bal.
United Kingdom	973	383	590	840	358	482	847	349	498	848	330	518	678	210	468
Canada	739	476	263	837	475	362	915	489	426	948	503	445	659	402	257
India, Malaya and Ceylon	66	590	—524	79	450	—371	68	384	—316	73	421	—348	56	269	—213
Newfoundland and Labrador	9	9	...	8	9	—1	9	10	—1	12	10	2	11	11	...
British West Indies	24	22	2	26	23	3	23	21	2	27	22	5	25	19	6
Australia	169	46	123	159	39	120	141	32	109	150	32	118	76	17	59
New Zealand	42	19	23	33	13	20	36	19	17	39	21	18	30	12	18
British Africa	65	42	23	71	34	37	77	34	43	82	43	39	53	30	23
Total Trade with British Empire	2,087	1,587	500	2,053	1,401	652	2,116	1,338	778	2,179	1,382	797	1,588	970	618
Total United States Trade with all Countries	4,809	4,431	378	4,865	4,185	680	5,128	4,091	1,037	5,241	4,399	842	3,843	3,061	782

	1931.			1932.			1933.			1934.			Average Balance.
	Ex.	Im.	Bal.	Ex.	Im.	Bal.	Ex.	Im.	Bal.	Ex.	Im.	Bal.	
United Kingdom	456	135	321	288	75	213	312	111	201	383	115	268	395·4
Canada	396	266	130	241	174	67	211	185	26	302	232	70	227·3
India, Malaya and Ceylon	43	152	—109	28	74	—46	23	111	—88	33	172	—139	—239·3
Newfoundland and Labrador	7	10	—3	4	7	—3	4	5	—1	5	5	...	—·8
British West Indies	17	14	3	10	8	2	9	4	5	13	6	7	4·0
Australia	27	13	14	27	5	22	26	8	18	43	9	34	68·6
New Zealand	13	4	9	9	2	7	8	5	3	13	6	7	13·6
British Africa	36	18	18	21	13	8	27	15	12	52	15	37	26·6
Total Trade with British Empire	995	612	383	628	358	270	620	444	176	844	560	284	495·4
Total United States Trade with all Countries	2,424	2,090	334	1,611	1,322	289	1,674	1,449	225	2,133	1,655	478	560·5

In the table which accompanies this article it will be noted that the only parts of the British Empire which consistently export more goods to the United States than they receive from that country are India, Ceylon and Malaya. Heavy United States imports of rubber, tin, tea and hemp account for this relationship. The net average value of the United States surplus commodity imports from these three parts of the Empire has averaged $239 million.

If the statistics given in the table which accompanies this article told the whole story, the burden of this relationship might be considered intolerable. The large expenditures in Canada of tourists from the United States, however, tend to bring about a better balance between the two countries than is generally appreciated. With due allowance for tourist trade it would seem that the United States has spent more for Canadian goods since 1931 than Canadians have spent in the United States. In a like manner, on balance, the United States pays heavy amounts to Great Britain for shipp'ng charges and insurance. The full details of the financial balance between Great Britain and the United States would make a long story. In no unbiassed accounting of the financial relationships between the two countries should these factors be overlooked.

Commodity balances have assumed special importance since the beginning of the depression. With most governments attempting to regulate their imports from each country in accordance with the sales to that country, the large import balance of the British Empire in its trade with the United States assumes special significance. In a theoretical world where all countries were buying in the cheapest markets and selling where they could get the best prices, unhampered by excessive tariffs and other trade restrictions, a lack of balance between two individual countries would deserve little special comment. Triangular relationships, for instance, would accurately and quickly offset such balances. In the present phase of extreme nationalism, however the subject becomes of major importance. At each Empire conference the other parts of the Empire seek an increasing share of the British market.

In allotting quotas to Empire countries, Great Britain cannot afford to overlook the needs of Argentina, Sweden, Norway and other countries which are large purchasers of British goods. Empire countries and many foreign countries have made and are willing to make heavy concessions in order to retain preferred access to the British market which absorbs a large proportion of the total surplus exports of the world. It is inevitable that if Great Britain is to continue to absorb excess goods from the United States, quotas for other countries must be smaller than would otherwise be the case. Certainly, the record would indicate that the time has come for the United States to make substantial concessions on goods from the Empire.

Over a period of many years Great Britain has recognised that with her large foreign investments a surplus of commodity imports is not a hindrance to prosperity. By accepting a surplus of goods from abroad provision has been made for other countries to pay service charges on existing loans. It is not entirely an accident that Great Britain has received better returns on foreign loans than has been the experience of other countries. New countries do not have the financial resources with which to meet emergencies. It remains for wealthy and mature countries to assume the reponsibility of maintaining equilibrium during a depression. By assisting rather than restricting trade, by deliberately purchasing more than they sell during such a crisis, they can mitigate the difficulties with which the world is confronted. Such measures, together with wise financial policies, create conditions under which new countries can continue to make payments to them on debt services. In maintaining a large import balance throughout the depression Great Britain has made a notable contribution toward creating conditions favourable for a revival of world trade in less developed countries, and this revival, in turn, will tend to produce an improvement in British exports.

The Effects of Thermic Treatment upon the Physical Properties of Aluminium Alloys

By J. TOWNS ROBINSON,
Metallurgist, High Duty Alloys, Ltd.

In a previous article[1] the writer briefly outlined some important factors upon which the successful heat-treatment of aluminium alloys principally depended. It is, therefore, the object of this article to review the resultant physical properties, after heat-treatment, of the various well-known alloys. The author deals briefly with the casting alloys and gives more attention to the wrought alloys.

I THINK it will be recognised that at no other period in the history of the aluminium industry has the physical characteristics of the alloys borne such an important relation to the progress and development of international industry, and one is tempted to say the future destiny of nations, than at the present time. Increased performance, efficiency, and rating of engines, whether for the ordinary commercial motor-vehicle or the highly developed aero engine, demands the very highest physical properties obtainable, and these can only be achieved by a high standard of both scientific and industrial technique

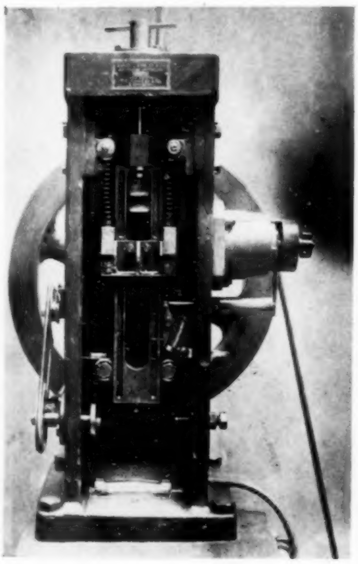


Fig. 1.—Amsler repeat impact testing machine

It must be borne in mind that although the composition of the alloys is fundamentally the foundation or basis, their resultant physical properties are only developed by correct working and thermic treatment. In this respect great praise is due to the art of metallography, and the metallographist who has been able to study the structural constitution or make up, a knowledge of which is essential, to correctly control and interpret the physical properties in their true perspective. This is particularly applicable to aluminium alloys, owing to the highly complex nature of their constitution and the difference in solubility of the alloying elements, the correct "fixation" of which by mechanical work and treatment is necessary for physical stability, and ultimate strength and hardness.

It is proposed in this article to deal very briefly with the casting alloys, and to consider more fully the wrought alloys owing to their greater strength and use for the more important parts of present-day engines. It will be necessary to repeat certain characteristics which have already been published by various authors, but it is hoped that other characteristics will be of interest and the various physical forms or conditions visualised.

The principal high-strength casting alloys in use at the present time are "Y" alloy, the Hiduminium alloys, R.R. 50, R.R. 53, and R.R. 53B, and the Silumin alloys, "Beta" and "Gamma," the latter being largely used in Germany, but have so far found little favour in this country. The alloy most extensively used of this series for highly

1 "Some Factors Governing the Heat-treatment of Aluminium Alloys," METALLURGIA, March, 1935.

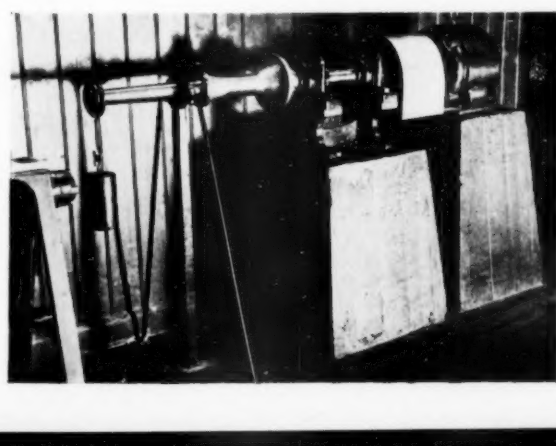
TABLE I.

Alloy	As Cast. Energy of Blow. 0·054 ft.-lb.	0·122 ft.-lb.
L. 5	143,140	18,140
	141,720	22,550
	213,550	16,290
	190,230	20,440
	140,120	10,730
	144,680	16,420
Average	162,240	17,428
L. 11	40,420	10,180
	42,050	17,200
	45,010	14,360
	46,000	26,370
	44,090	18,680
	41,080	13,710
Average	43,108	16,750

Alloy.	As Cast. Energy of Blow. 0·054 ft.-lb.	0·122 ft.-lb.	0·216 ft.-lb.
Aluminium Silicon 12%Si.	20,900	5,130	—
	37,520	4,100	—
	27,300	2,600	—
	29,450	1,973	—
	30,210	2,240	—
	28,110	3,740	—
	28,915	3,297	—
Aluminium Silicon 12% Si. 0·3% Mg. 0·5% Mn.	566,295	40,728	1,910
	Average 6 Tests. Heat-treated. Quenched and aged.		

Alloy. Hiduminium.	As Cast. Energy of Blow. 0·054 ft. lb.	0·122 ft. lb.	Heat Treated. Energy of Blow. 0·054 ft. lb.	0·0122 ft. lb.	0·216 ft. lb.
R.R. 50	219,970	76,680	507,260	155,750	2,860
	190,730	29,880	570,240	181,600	6,690
	240,800	71,150	562,740	178,450	2,940
	178,080	60,460	684,300	187,400	4,860
	173,840	67,760	459,750	108,960	3,470
	220,430	80,150	626,010	114,510	5,840
Average	203,975	64,346	568,220	154,345	4,443
R.R. 53	1,000,000	84,790	1,000,000	251,610	12,280
	unbroken	80,730	unbroken	296,330	7,510
	"	127,880	"	254,980	9,300
	"	85,550	"	314,200	11,510
	"	80,620	"	228,150	10,840
	"	81,640	"	213,710	8,490
Average	—	90,200	—	259,830	9,988
R.R. 53 B.	—	—	1,000,000	320,300	50,040
	—	—	unbroken	387,600	24,400
	—	—	"	397,150	17,500
	—	—	"	387,900	31,700
	—	—	"	378,850	35,140
	—	—	"	—	27,300
Average	—	—	—	373,000	32,000
"Y" Alloy	23,700	3,680	1,000,000	150,870	3,490
	50,900	8,800	unbroken	111,320	3,520
	39,050	2,020	"	130,210	2,780
	58,030	2,740	"	121,400	4,540
	24,710	7,300	"	140,100	3,800
	30,320	5,430	"	139,110	3,720
Average	37,796	4,995	—	132,168	3,641

Fig. 2.—Whirling rig or rotating fatigue machine.



stressed parts is the Hiduminium R.R. 50. This alloy is unique in the fact that it attains its full physical properties after a low temperature or precipitation treatment only. This feature is more remarkable when it is understood that this alloy has much superior impact fatigue and deformation loading properties than the high-strength fully heat-treated "Y" or Silumin Gamma alloys.

TABLE II.

WHIRLING RIG OR ROTATION FATIGUE TESTS.

For test-piece, see Sketch.

Revs. per min., 1,400. Tests run, 10 hours with 200 lb. load, subsequent loading being 20 lb. at 2-hour intervals.

Alloy.		Max. Load Applied.	Time.
Silumin Gamma	(1)	480 lb.	37¼
Heat-treated	(2)	480 lb.	37¼
R.R. 50	(1)	520 lb.	40¾
Heat-treated	(2)	580 lb.	46¾

Fig. 1 shows the Amsler repeated impact testing machine, which has given much valuable information concerning the physical properties of alloys. This machine combines impact with fatigue effect, and the opinion is held that this form of test bears a greater relation to conditions of general design and working parts in service than any other test.

Specimens cut from bars 1 in. dia. × 6 in. long.
Cast in B.S.I. sand-lined moulds.
Size of test specimen 0.5 in. dia., 1 in. long.
Rate of loading 0.2 tons per sq. in. per second.
Black area represents 0.1% permanent set.
Open area represents 0.5% permanent set.

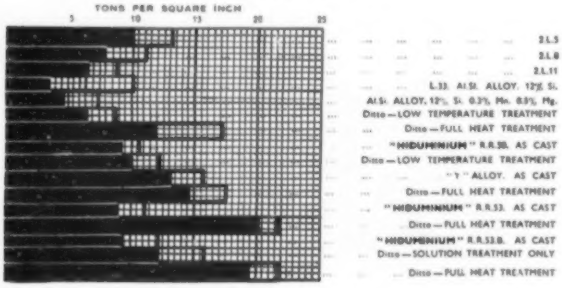


Fig. 3.—Compression strength of sand-cast test-pieces.

Specimens cut from bars 1 in. dia. × 9 in. long.
Cast in iron moulds, ½in. wall thickness.
Size of test specimen 0.5 in. dia., 1 in. long.
Rate of loading 0.2 tons per sq. in. per second.
Black area represents 0.1 permanent set.
Open area represents 0.5% permanent set.

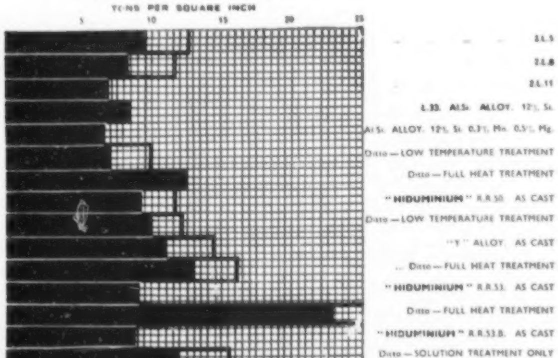


Fig. 4.—Compression strength of chill-cast test-pieces.

Table I. gives a series of results obtained on this machine on the casting alloys from test-pieces machined from standard chill-cast test-bars. These figures reveal interesting physical characteristics, particularly when studied in conjunction with the ordinary tensile properties of these alloys. The R.R. 53B alloy, which has been recently developed to give greater ductility with high strength, stands out very strikingly under this test.

Another form of test for comparative fatigue is shown in Fig. 2, which employs an actual sand casting as a test-piece, so designed to give an abrupt change of section and

TENSILE TEST PIECES taken from Actual SAND CASTINGS

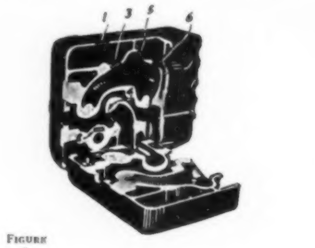


FIGURE 1

FULLY HEAT TREATED.

WATER COOLED CYLINDER HEAD CASTING.

FIGURE 1.

	Ult. Stress Tons per sq. in.	Elongn. % on 2"	Brinell Hardness
Position 1.	18.0	3.0	129.
2.	16.6	1.5	124.
3.	17.6	2.0	129.
4.	16.0	1.5	129.
5.	16.5	2.0	129.
6.	16.0	3.0	129.

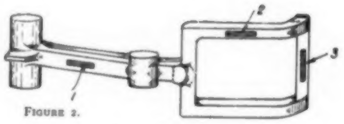


FIGURE 2.

LEVER CASTING.

FIGURE 2.

Position 1.	18.5	2.0	134.
2.	22.25	3.0	134.
3.	22.25	2.5	134.

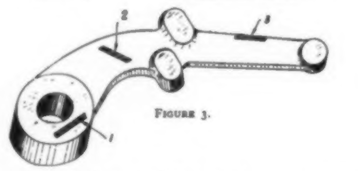


FIGURE 3.

LEVER CASTING.

FIGURE 3.

Position 1.	19.0	2.0	129.
2.	21.2	2.5	129.
3.	19.5	2.0	129.

TENSILE STRENGTH OF CHILL CAST HEAT TREATED BARS AT ELEVATED TEMPERATURES.

Temperature of Test.	Ultimate Stress. Tons per Sq. In.
Normal	24.20
200° C.	20.10
250° C.	17.60
300° C.	14.00
350° C.	7.70

BRINELL HARDNESS AT ELEVATED TEMPERATURES. HEAT TREATED.

	Chill Cast.		Sand Cast.	
Temperature of Test.	Hardness No.	Recovery after Cooling.	Hardness No.	Recovery after Cooling.
Normal	138	—	129	—
100° C.	129	138	117	129
150° C.	117	138	107	129
200° C.	90	138	85	129
250° C.	72	125	67	117
300° C.	40	95	34	85
350° C.	22	69	21	65

Fig. 5.—Tensile test-pieces taken from actual castings.

concentration of stresses. Fatigue takes place by progressive loading. Table II. gives comparisons of R.R. 50 and Silumin heat-treated alloys, and here again the lower strength alloy gives the superior results. These two latter forms of testing demonstrate physical characteristics entirely unrelated to the tensile properties of the alloys.

In the case of the Silumin heat-treated alloy, it is possible that this test demonstrates the presence of internal stresses

TABLE III.

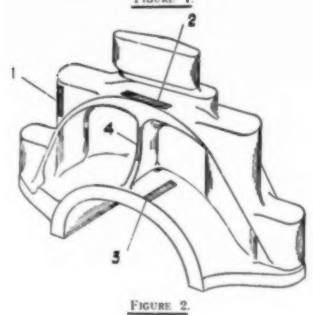
AMSLER REPEATED IMPACT TEST.

All tests taken from 1¼ in. square forged bar heat-treated to give specification figures. The results at each setting of six tests are given.

1ST SERIES. Energy of blow, 1·16 ft.-lb. No. of blows per min., 620.				3RD SERIES. Energy of blow, 0·351 ft.-lb. No. of blows per min., 340.			
Test.	R.R. 56.	"Y" Alloy.	Dural.	Test.	R.R. 56.	"Y" Alloy.	Dural.
1	4,770	170	160	1	326,100	113,180	99,450
2	6,320	210	150	2	230,390	69,980	67,580
3	6,335	200	150	3	370,920	359,920	90,440
4	5,000	210	145	4	207,110	148,520	115,100
5	4,510	165	150	5	197,970	107,870	72,000
6	6,820	165	150	6	324,820	105,780	64,870
Highest	6,820	210	160	Highest	370,920	159,920	115,100
Lowest	4,510	165	145	Lowest	197,970	69,980	64,870
Average	5,626	187	151	Average	276,218	117,541	84,906

2ND SERIES. Energy of blow, 0·517 ft.-lb. No. of blows per min., 620.				4TH SERIES. Energy of blow, 0·156 ft.-lb. No. of blows per min., 340.			
Test.	R.R. 56.	"Y" Alloy.	Dural.	Test.	R.R. 56.	"Y" Alloy.	Dural.
1	103,770	53,030	34,440	1	1,000,000	255,460	226,430
2	98,000	70,050	39,820	2	1,000,000	255,940	333,970
3	100,500	65,850	39,420	3	1,000,000	478,800	195,620
4	107,210	52,500	32,450	4	1,000,000	148,470	247,550
5	105,360	58,800	41,760	5	1,923,000	619,150	224,280
6	90,150	—	—	6	All above tests unbroken	361,840	248,440
Highest	105,360	70,050	41,760	Highest	Unbroken	619,150	333,970
Lowest	90,150	52,500	32,450	Lowest		148,470	195,620
Average	100,832	50,038	37,578	Average	—	353,276	246,045

FIGURE 1.



TENSILE TEST PIECES TAKEN FROM ACTUAL STAMPINGS. FULLY HEAT TREATED.

BEARING CAP.

FIGURE 1.

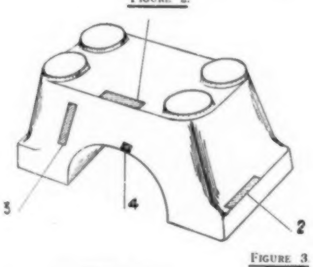
	Ultimate Stress Tons per sq: in.	Elongation %	Brinnell Hardness
Position 1.	27.75	16.0	138
2.	27.0	10.0	129
3.	27.0	15.0	134
4.	28.0	16.0	138

BEARING CAP.

FIGURE 2.

Position 1.	27.5	10.0	134
2.	27.0	13.0	134
3.	27.0	10.0	134
4.	27.5	12.0	138

FIGURE 2.



DIESEL ENGINE CONNECTING ROD.

FIGURE 3.

Position 1.	27.0	10.0	134
2.	27.0	10.0	129
3.	26.9	12.5	134
4.	27.3	15.0	129
5.	27.2	12.0	129
6.	27 1	12.5	134

FIGURE 3.

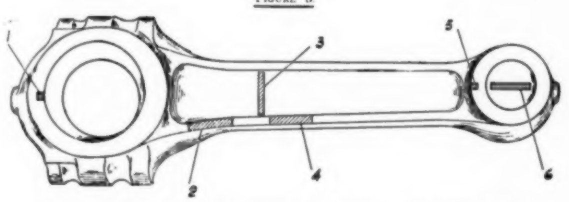


Fig. 7.—Tensile test-pieces taken from actual stampings.

in the casting or test-piece, due to quenching from a high temperature. As this type of alloy is very weak and of low strength at the solution treatment temperature, it is possible that whatever ductility is available is rendered negative by accommodation of the quenching stresses imposed, and therefore the final or fully heat-treated test-piece is entirely lacking in resistance to stand up or accommodate itself to impact forces. It must be remembered, of course, that all casting alloys, when subjected to the high temperature solution treatment, must naturally contain varying amounts of internal stress, and it is only by carefully studying these effects that these alloys will give satisfaction in service.

Fig. 3 gives the compression strength of sand-cast test-pieces, and Fig. 4 that of chill-cast. In these tests the 0·1% and 0·5% permanent set or proof stress have been taken, which give interesting results. The compression strength of these alloys bears a much closer relation to their tensile strength. Fig. 5 gives the tensile and hardness properties of the R.R. 53B alloy taken from actual castings, also the same properties of chill-cast bars at elevated temperatures. The uniformity and consistency of these results are proof of controlled casting and heat-treatment operations. This alloy has also a fairly good strength, with very good ductility in the solution-treated condition only, and is perfectly stable in this condition.

TABLE IV.
TENSILE STRENGTH WROUGHT ALLOYS.

Alloy.	0·1% Proof Stress, Tons per Sq. In.	Ultimate Stress, Tons per Sq. In.	Elongation, % on 2 in.	Brinell Hardness.
R.R. 56	22·00	28·00	12·0	138
" Y "	13·00	25·00	18·0	110
Duralumin	13·50	25·00	20·0	110

Wrought Alloys.

The wrought alloys of aluminium receive much more attention than the cast alloys, and this is only natural considering that they are used for the more highly stressed parts. Considerable progress has been, and is being, made in the technique of fabrication on the wrought alloys. The principal alloys in use, such as Duralumin " Y " and the Hiduminium R.R. alloys, are well known, and we have the more recent introduction of the super-Duralumins and 24 S alloys, this alloy also being available as Hiduminium 72; these latter particularly in the form of extruded sections and sheets.

Test-pieces cut from 1¼-in. sq. forged bar. Fully heat treated and machined to 0.5 in. dia. by 1 in. long. Rate of loading = 0.2 tons per sq. in. per second.
Black section represents 0.10% proof stress.
Open section represents 0.50% proof stress.

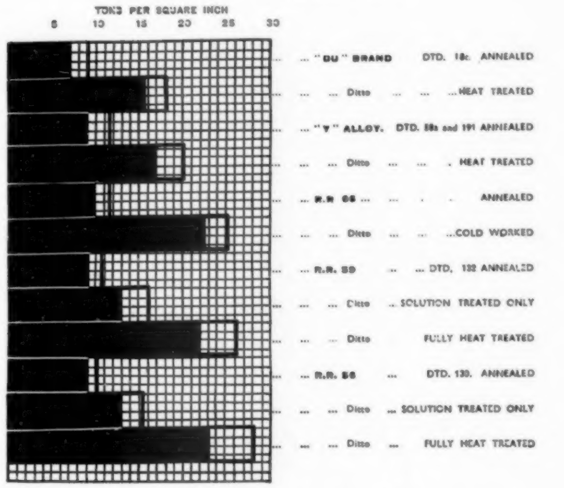


Fig. 6.—Compression strength of wrought alloys.

The resultant physical properties of the wrought alloys depend to a very considerable extent on the original crystal structure of the cast ingot, and unless this is of a suitable degree of fineness, it is impossible to obtain the full physical properties no matter how carefully controlled the working and heat-treatment operations have been.

It does not appear to be yet generally recognised that the standard tensile test will not detect overheating in aluminium alloys. It is possible to have a fairly serious degree of overheating, and yet the tensile test will give slightly increased figures up to the stage where incipient fusion has taken place. Overheating is much more readily detected by some form of twist or bend test.

Table III gives the results of the wrought alloys when subjected to the amsler repeated impact fatigue test, as

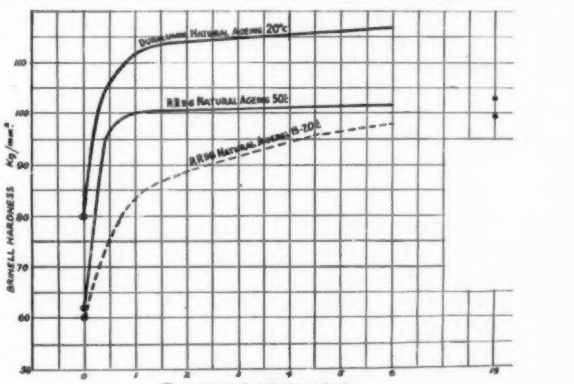


Fig. 8.—Chart shows the effect of ageing on R.R. 56 and Duralumin sheet.

illustrated in Fig. 1. Here again, as in the case of the cast alloys, this form of test shows remarkable differences in the physical characteristics. It is interesting to study these results in relation to the standard tensile test on Table IV. It will be noted that the R.R. 56 alloy, with its high-proof stress but lower elongation, is very much superior to " Y " or Duralumin, with their lower-proof stress and higher elongation.

In the R.R. 56 material, which has a refined crystal structure, the elongation is concentrated at the point of

fracture, but with a material of a more fibrous structure the elongation is distributed over the whole length of the bar or specimen.

Fig. 6 shows the compression strength of the wrought alloys in the form of 0·1% and 0·5% proof stress. The high maximum strength values sometimes given are inclined to be somewhat misleading, as aluminium alloys flow under pressure, therefore, when fracture occurs, the actual area is very much greater than the original area used in calculating the results. The higher-proof stress alloys in tension likewise give the higher value under compression loads. Fig. 7 gives a series of stampings in R.R. 56 alloy, from which tensile tests have been taken in various directions. The results are strikingly uniform in character, and indicate correct grain size, manipulation, and heat-treatment.

"Y" alloy and Duralumin are relatively soft after quenching, but rapidly age-harden and attain their full physical properties after about five days natural ageing, whereas, on the other hand, the R.R. 56 alloy is practically stable after quenching, and must be subjected to a low temperature or precipitation treatment to obtain the necessary physical properties. Fig. 8 is a chart showing the effect of ageing on R.R. 56 and Duralumin sheet. The chart shows that a certain amount of age-hardening occurs during the first day after quenching R.R. 56 sheets, after which the material is comparatively stable in the solution-treated condition, and does not attain full properties without the artificial ageing treatment. Duralumin sheet, on the other hand, starts at 80 Brinell hardness, and goes up to 112 hardness in the first day, and reaches its final hardness in the course of natural ageing. The stability of the R.R. 56 alloy in the solution-treated or quenched condition is of particular advantage as applied to sheets and extruded sections, as manipulative work, such as bending and forming, can be carried out in the relatively soft condition even after storage for some time, and the parts finally given the artificial ageing treatment.

At the present time the Duralumin "G," 24 S, and Hiduminium 72 alloys are being advocated in the form of extruded sections and sheets, owing to their high physical properties in the solution-treated condition only—namely, over 20 tons per sq. in. proof stress and 30 tons per sq. in. ultimate stress. In the first instance, it must be remembered that these alloys will only give these physical properties in the extruded or rolled condition. In the form of forgings and stampings they give physical properties very little, if any, superior to ordinary Duralumin or "Y" alloy in the solution-treated condition.

Tests were carried out on one of these alloys of the Duralumin G or Hiduminium 72 = 24 S composition as follows :—

1 in. Diameter Extruded Bar.	0·1% Proof Stress, Tons per Sq. In.	Ultimate Stress, Tons per Sq. In.	Elongation % on 2 in.	Brinell Hardness.
Quenched from 490° C.—				
Natural aged 1 day	19·20	31·00	14·0	134
,, ,, 5 days	22·00	32·00	14·0	138
Forged to ¾ in. diameter; quenched from 490° C.—				
Natural aged 1 day	16·00	28·20	23·0	129
,, ,, 5 days	17·10	28·60	21·0	138

These are typical figures and tests carried out on other sizes of extruded bars confirmed these results. It will be noted in the above tests that practically no natural ageing occurs in the forged condition with this type of alloy after the first day. Similar results to the latter are obtained with this composition of alloy in the forged condition, working from the cast ingot. A 3¼ in. square cast ingot forged down to 1 in. square after solution-treatment gave the following results :—

	0·1% Proof Stress, Tons per Sq. In.	Ultimate Stress, Tons per Sq. In.	Elongation, % on 2 in.	Brinell Hardness.
Natural aged 1 day	15·20	28·50	24·0	125
,, ,, 5 days	16·60	29·30	23·0	134

It is also of interest to study the effect of the composition with relation to the manganese content between this class of alloy. The composition and physical properties in the extruded condition are as follows :—

	Hiduminium 72. %	Duralumin "G." %
Copper	4·00	4·40
Manganese	0·60	0·83
Magnesium	1·50	1·48
Iron	0·31	0·30
Silicon	0·30	0·20
Aluminium	Remainder	Remainder

	0·1% Proof Stress, Tons per Sq. In.	Ultimate Stress, Tons per Sq. In.	Elongation, % on 2 in.	Brinell Hardness.
1 in. dia. Extruded Bars Hid. 72 Alloy, quenched 490° C.—				
Natural aged 1 day	20·00	32·20	18·0	121
,, ,, 5 days	22·00	34·00	15·0	138
Duralumin "G," quenched 490° C.				
Natural aged 1 day	16·20	31·50	18·0	121
,, ,, 5 days	22·80	33·90	15·0	138

It is noted that the increase in manganese to 0·83% does not increase the strength of the alloy, likewise taking the manganese up to 1% was equally ineffective.

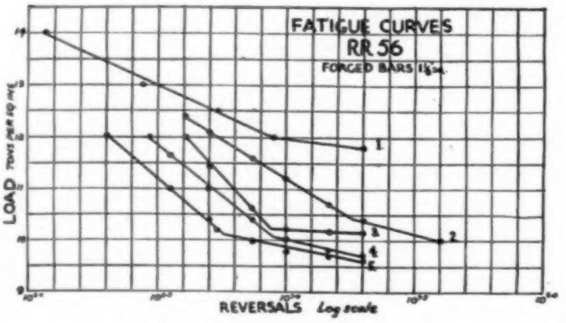
The following test conducted on a built-up strut or spar and stressed to represent service conditions affords an interesting comparison of the physical properties under these conditions of Duralumin, 24 S and R.R. 56 in the extruded forms.

SPAR TEST SUMMARY.

	Spar Test Results.		Control Test Results.	
Spar Section.	"E," Lb. per Sq. In.	Failing Stress, Tons per Sq. In.	0·1% Proof Stress, Tons per Sq. In.	Ultimate Stress, Tons per Sq. In.
	10·2 × 10⁶	13·13	15·85	22·75
Do. R.R. 56 flange L. 3 web	9·8 × 10⁶	19·00	21·55	25·4
Do. S.T. 24 flange L. 3 web	8·1 × 10⁶	16·1	19·62	26·6
	11·25 × 10⁶	21·3	22·35	26·25
Do. Secn. in 3 L. 1	10·9 × 10⁶	13·43	15·45	24·3
Do. 24 S.	9·5 × 10⁶	19·36	20·84	29·45

The failing stress in each test is very much superior in the R.R. 56 to the other alloys.

In considering the fatigue values of the wrought alloys,



1. Parallel specimen, cold worked.
2. ,, ,, normal treatment.
3. ,, ,, special treatment.
4. Tapered specimen, normal treatment.
5. ,, ,, special treatment.

Fig. 9.—Fatigue values of wrought R.R. 56 alloy.

	.1% P.S. Tons/ sq. in.	Yield Tons/ sq. in.	Ultimate Tons/ sq. in.	Elongation %.	Reduction %.	Hards No.
2 and 4, standard heat treatment	22.0	—	27.9	15.0	—	138
3 and 5, special treatment for high ductility	15.5	—	26.8	24.0	—	117
1, cold worked after solution treatment and aged	27.0	—	32.2	6.5	—	148

the effects of different heat-treatments and the shape of the test-piece used should be studied for each respective alloy. Fig. 9 shows the results of these effects on the R.R. 56 alloy, the tensile properties of which are given above. Fatigue curves show that the fatigue limit of the material does not

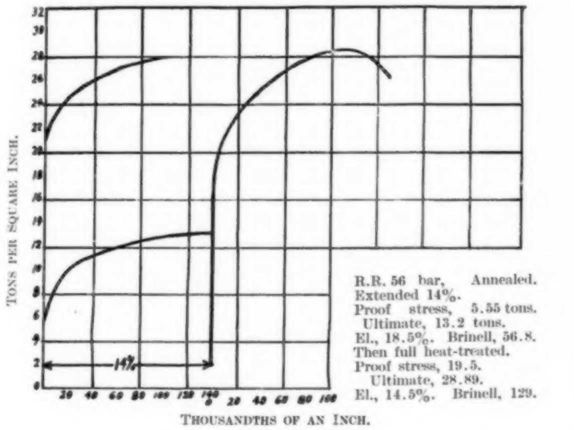


Fig. 10.

depend upon the elongation values, but solely upon the ultimate stress and elastic limit. A specimen cold-worked to give high elastic limit and ultimate stress and low elongation values gives a higher fatigue limit than material with low elastic limit but high elongation.

The shape of the specimen influences the results in that a test-bar tapered to give equal stress along the whole length gives higher values for a material that is capable

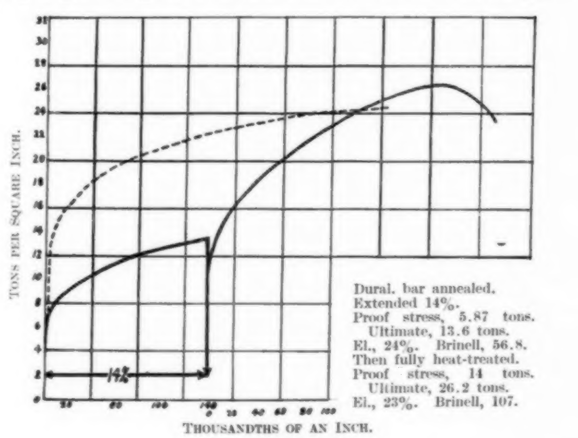


Fig. 11.

of work-hardening than a parallel specimen of the same material. Slight changes in crystal structure along the parabolic test-piece will cause the qui-stressed specimen to fracture at the weakest point, giving a minimum value for every bar tested. The point of fracture is fixed for parallel bar, and an average figure is obtained which only coincides with the shaped bar when the weakest point coincides with the point of maximum bending moment.

A considerable amount of research work and investigation has been done on the effects of cold working on the physical properties of aluminium alloys, and an article by K. Guler " On the Treatment of Light Alloys (Avional and Duralumin) " is a valuable contribution. Experiments on these lines have been carried out in the laboratory of the writer on R.R. 56 and Duralumin sheets and bars, which confirm the findings of Dr. Guler.

In these tests a definite amount of cold work or deformation in the measure of 14% of the original length was given to the R.R. 56 and Duralumin alloys in the sheet form, by means of stretching in the tensile testing machine, and on the bars by extending under the drop-hammer. This percentage of cold work was imparted to the alloys in the annealed and solution-treated conditions, and the bars afterwards aged only and full heat-treated, and the resultant physical properties compared against the original standard figures. Figs. 10 to 15 give typical example of these tests.

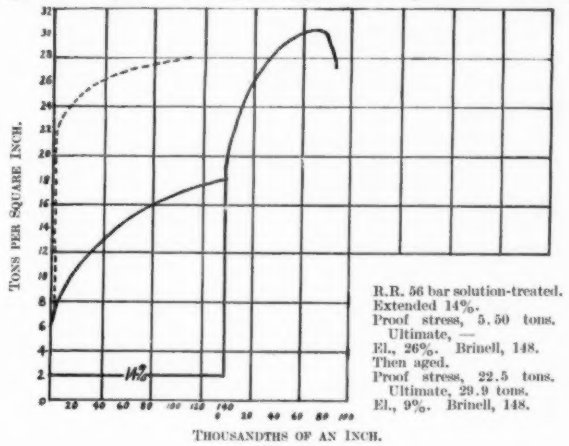


Fig. 12.

The graphs shown in Figs. 10 to 15 show that cold working after solution treatment accelerates the ageing effects and gives rise to an increase in proof stress and ultimate stress, with loss in ductility. Complete re-treatment, however, restores the elongation value, and providing the amount of cold work was in excess of 2 or 3%, also retains a refined structure, giving a marked increase in ultimate stress values.

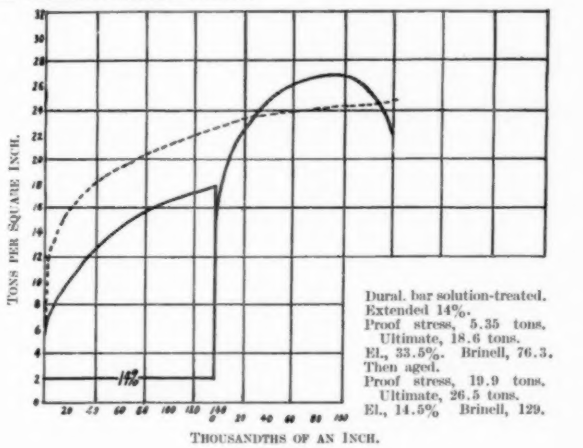


Fig. 13.

Figs. 10 *to* 15.—*The effects of cold working in conjunction with various heat-treatments on* R.R 56 *and Duralumin bar.* (*Dotted lines on all charts show standard test after normal heat-treatment.*)

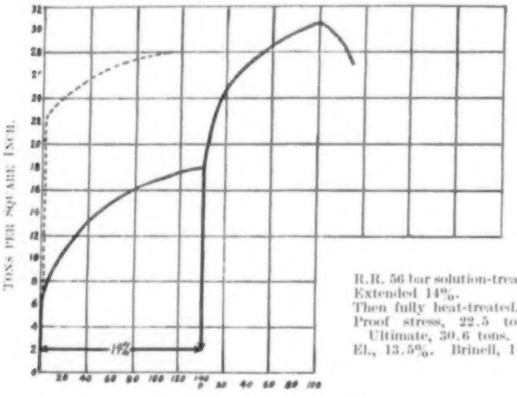
Cold working of the order of 1 to 2%, on the other hand, induces excessive crystal growth during re-treatment above the recrystallisation temperature, causing low elastic limit values, and high elongation figures.

In general, the results show that re-heat treatment after cold working, completely obliterates the hardening effects of the cold working, and that the resulting properties depend upon whether the refined crystal structure, induced by cold working is retained, or whether crystal growth occurs and increases the elongation values.

In the case of the R.R. 56 bars, whether cold worked

after the solution treatment or after annealing, re-heat-treatment has caused an increase in the elongation value after re-testing. This is when the cold work is applied by means of a 14% stretch on the testing machine.

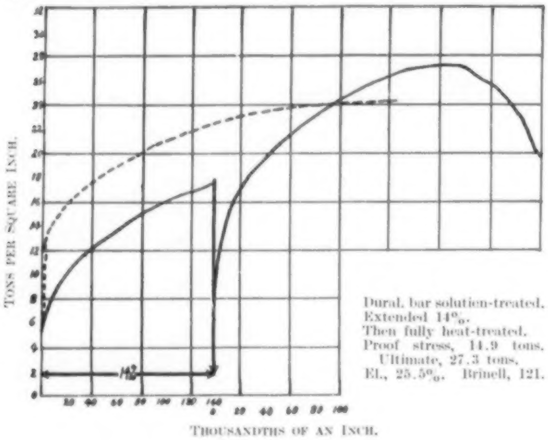
The Duralumin bars, however, show an increase in proof stress and ultimate stress at the expense of elongation, showing that the crystal size was at a maximum in the original bar, and that the crystal refinement obtained in the cold working was not completely restored by heat-treatment.



R.R. 56 bar solution-treated.
Extended 14%.
Then fully heat-treated.
Proof stress, 22.5 tons.
Ultimate, 30.6 tons.
El., 13.5%. Brinell, 148.

Fig. 15.

When the R.R. 56 bars are extended under the hammer, the proof stress and ultimate are greatly increased, with a slight diminuation of elongation. This is due to the fact that the amount of work put into a bar to extend it 14% is much greater when applied in this manner than when applied by simple tension, owing to the material spreading



Dural. bar solution-treated.
Extended 14%.
Then fully heat-treated.
Proof stress, 14.9 tons.
Ultimate, 27.3 tons.
El., 25.5%. Brinell, 121.

Fig. 14.

at the same time. The crystal refinement is therefore much greater and does not recover fully on re-heat treatment. A much smaller amount of cold working is necessary under the hammer, therefore, to obtain results comparable to those obtained when the stretching is done by simple stretching.

In general, cold work applied in the solution-treated condition has more influence on the final results after re-heat treatment than that applied in the annealed condition.

In Duralumin sheet and bar an optimum crystal size is attained in the normal heat-treated material, and cold working leaves a finer crystal structure and hence improvement in proof stress and ultimate at the expense of elongation. In R.R. 56, however, which has a very fine crystal size in the normal state, a small amount of cold working will induce crystal growth and increase in elongation after re-heat treatment, while greater amounts of cold deformation preserve the high proof stress and does not change the elongation figures.

It must be remembered that forging and stamping, as well as castings in aluminium alloys, when subjected to the high-temperature solution treatment and quenched, have all to some degree locked up internal stresses. This subject is receiving much thought and attention at the present time, and research is being conducted into various means of ascertaining and determining the amount of such stress by the X-ray crystallographic and stress measurement methods.

Base Metal Production.

ALTHOUGH world prices for base metals have not yet regained the high levels reached in the summer of 1934, the trend has been definitely upward since the beginning of the year, according to the Monthly Letter of the Royal Bank of Canada. Prices for standard copper in London rose from an average of £28 2s. 3d. per long ton in January to £31 7s. 6d. on April 23. During the same period prices for lead and zinc increased from £10 6s. 5d. and £12 per ton to £12 8s. 9d. and £13 5s., respectively.

In the January, 1935 issue of this Monthly Letter there was a discussion of the sbustantial gain in Canadian output of base metals during 1934. Not only has this gain been contibued during the early months of the present year, but the available statistics of production in othercountries indicate that the increased output of the principal non-ferrous metals has been world-wide.

METAL PRODUCTION.
(Short tons.)

	Canada.			World.	
	1934.	1933.		1934.	1933.
Aluminium	15,500	16,200	..	188,400	155,400
Copper	182,823	149,491	..	1,363,100	1,101,360
Lead	172,813	133,237	..	1,483,000	1,339,600
Nickel	64,408	41,632	..	70,500	46,500
Tin	—	—	..	126,700	110,500
Zinc	149,352	99,566	..	1,295,500	1,109,300

During this period of expanding production, however, the trend has been increasing in the direction of regulation in relation to demand. International cartels now control the major part of the world's output of copper and tin, and the base-metal mining industries of the United States are operating under N.R.A. codes. The international copper agreement, which was concluded at the end of March, aims at the reduction of output necessary to permit the gradual liquidation of present supplies, and does not include the pooling of sales or price fixing; the elimination of large stocks is the principal objective. It is understood that Canadian mines whose copper is largely a by-product will co-operate in the orderly marketing plan. As a result of the restriction of tin production in the past three years, world stocks have been reduced from a peak of 60,000 tons in April, 1932 to 19,000 tons on March 31, 1935, and the International Committee has permitted an increased production during the second quarter of this year.

In general, consumption of base metals has kept pace with production. Continued improvement in manufacturing activity, particularly in the automobile industry, expansion in public and private construction in some countries, notably Great Britain, and the developmnt of new uses for the various metals have all contributed to the increase. In some industries the gain in recent months has been spectacular. The tinplate industry in the United States, for example, has been operating for the past six weeks at a rate in excess of that attained in 1929, and it is anticipated that total output during the present year may establish a new record.

A silver lining brightens Canada's mining picture as the price of the white metal gradually nears the statutory goal of $1·29 an ounce set by the United States Government in pursuance of its policy to place its gold-silver ratio on a three-to-one basis. As the world's third largest producer of silver, Canada stands to benefit materially from the rise.

The Installation and Maintenance of Thermo-Electric Pyrometers

By G. H. BARKER

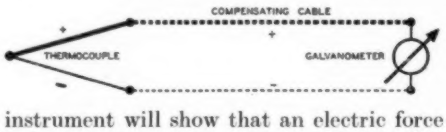
The influence of heat upon the quality and cost of nearly all manufactured products necessitates a thorough understanding of the underlying principles involved and the possibility of controlling the many variable factors affecting the conduct of heating operations. Control of temperature is generally considered the most essential factor, and to facilitate this thermo-electric pyrometers are now almost indispensable. In this article the author considers, briefly, the operating principles of thermo-electric pyrometry, and the construction of the indicating, recording and controlling instruments and their sensitive elements.

FEW industrial processes involving the application of heat in excess of 300° C., are conducted to-day without the aid of thermo-electric pyrometers. Their wide industrial employment—which has extended so rapidly during recent years—has been responsible for many changes in construction and improvements in design. Consequently, it is more than ever true to say that poor performance in the majority of instances results from (*a*) improper installation, (*b*) failure to maintain the associated thermocouples and compensating leads in good condition, and (*c*) lack of knowledge of the fundamental principles involved.

It is the purpose of these notes to assist actual and prospective users of thermo-electric pyrometers to improve the return on their investment by reporting the factors upon which good operation depends and the periodical inspections and tests which are essential to their economical maintenance. As a preliminary, it seems desirable to consider, briefly, the operating principles of thermo-electric pyrometry and the construction of the indicating, recording and controlling instruments and their sensitive elements.

Operating Principle (*Millivoltmeter-type Pyrometers*). As is well known, if two wires of dissimilar metals be joined at one end, and that end be immersed in a hot zone whilst the opposite or cold end is connected to a sensitive milli-

Fig. 1.—Single thermo-electric circuit.



voltmeter, the instrument will show that an electric force is present and causing current to flow in the metallic circuit. A diagram of a simple thermo-electric circuit is given in Fig. 1.

If the circuit be made properly, the current generated will depend upon the difference in temperature between the two ends of the thermocouple—*i.e.*, the welded end which extends into the hot zone and which is termed the "hot junction," and the opposite, or outside end which is termed the "cold junction." As the e.m.f. developed is proportional to the temperature rise at the hot junction, the millivoltmeter may be calibrated in degrees Fahrenheit or Centigrade, and thus become a temperature indicator.

Obviously, any variation in the cold junction temperature must be taken into account in reading the instrument. Formerly, it was the practice to maintain the cold junction at as constant a temperature as possible by means of vacuum flasks, water-cooled jackets, etc., the zero of the instrument being adjusted frequently to correspond to the vacuum flask or other cold junction temperature. With modern pyrometers this point is taken care of by employing special connecting leads, known as compensating leads, between the thermocouple and the instrument terminals. These leads transfer the cold junction to the instrument itself, which incorporates an integral automatic cold junction compensator. This comprises a thermostatic spiral or helix connected to the control spring of the indicating or recording pyrometer movement. It is so calibrated that for every increase or decrease in the cold junction temperature, an equal correction is automatically effected in the instrument reading. As is well known, the deflection of a thermostatic spiral is directly proportional to the change in temperature of its surrounding medium.

The compensating leads are of the same metals, or of metals having together the same thermo-electric characteristics, as the thermocouple wire in the range of cold junction temperatures. The cold junction error is, therefore, limited to changes in the temperature of the air surrounding the instrument, and the automatic compensator automatically adjusts the pointer to allow for it.

The millivoltmeter (deflectional) pyrometer is of the moving coil type—*i.e.*, it consists of a wire-wound coil,

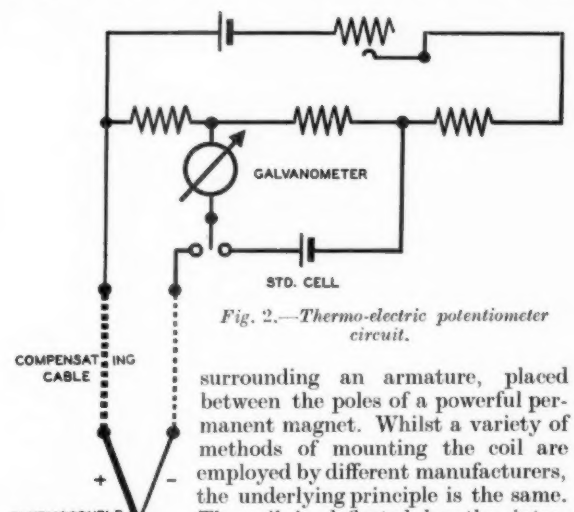


Fig. 2.—Thermo-electric potentiometer circuit.

surrounding an armature, placed between the poles of a powerful permanent magnet. Whilst a variety of methods of mounting the coil are employed by different manufacturers, the underlying principle is the same. The coil is deflected by the interaction of the magnetic field created by the current flowing through it and the magnetic field in which it is situated. The current flowing is proportional to the resistance of the circuit—which is fixed—and to the e.m.f. developed by the thermocouple which bears a fixed relation to the temperature difference between the hot and cold junctions. The pointer of the instrument is rigidly connected to the coil and as the coil is deflected it moves over the calibrated scale and thus reads the temperature being measured in degrees Centigrade or Fahrenheit.

Operating Principle (*Potentiometric type Pyrometers*). The essential difference between the millivoltmeter and the potentiometric pyrometer is that the energy required to move the pointer of the former is derived from the thermocouple itself, and in the latter the energy is provided by a fractional horse-power electric motor. In principle, the difference is that a secondary circuit is provided in the potentiometer—fed from a battery or mains unit. The potential drop across a portion of this circuit is balanced against the e.m.f. developed by the thermocouple. The

galvanometer is sensitive to the difference in potentials and remains undeflected when these are equal. Any difference in potential, arising from an increase or decrease in thermocouple-e.m.f. (resulting from a change in the measured temperature) causes the galvanometer to be deflected. This deflection sets in motion a restoring mechanism, which alters the potential of the secondary circuit until agreement is reached. As the recording mechanism is part of the balancing mechanism, this is moved over the chart and thus produces a record of the change in temperature which has occurred. A thermo-electric potentiometer circuit is shown in Fig. 2.

In other words, in millivoltmeter-type pyrometers, the e.m.f. developed by the thermocouple is measured directly by the galvanometer, but in the potentiometric instrument, this value is compared with the current in the secondary circuit and any difference is adjusted. The current in the secondary circuit must obviously be maintained at a given value, and this necessity divides potentiometers into two main classes—*viz.*, self-standardising and non self-standardising. In the self-standardising instrument a standard cell with a constant e.m.f. is substituted for the thermocouple periodically by the driving mechanism of the instrument, and additionally, a rheostat controlling the current in the secondary circuit is connected to the balancing mechanism. Any difference is adjusted so that the instrument is "standardised." In non self-standardising instruments, this adjustment has to be performed manually, so that the self-standardising instrument is the more desirable in industrial practice.

In recording instruments spring wound or electric clock-driven mechanism is introduced to depress the instrument pointer at given intervals on to an inked ribbon interposed between the pointer and the chart. The chart is driven continuously by the same clock. Consequently, the position of the pointer at the moment of depression is marked on the chart and the resultant series of dots thus made provides a continuous record of the temperature being maintained. With multi-point instruments, a change-over switch driven by the same clock is introduced and this connects the instrument movement successively to two or more thermocouples. A multi-colour ribbon with automatic change colour mechanism is employed in order that the various records may be readily distinguished.

In single-point potentiometric instruments—because of the power available—a wet ink pen may be used. In multipoint pyrometers, however, the ink ribbon—intermittent dot—method of recording is returned to.

In the case of controlling pyrometers, a similar depressor mechanism is usually employed to determine the position of contacts designed to actuate auxiliary gear through one means or another for the regulation of the heating medium in accordance with the temperature indication.

Whilst there are many types of control pyrometer, the most widely used is that in which a mechanically-operated selector system, driven by a small electric motor, determines the position of one or more enclosed mercury switches. This method avoids the disadvantages of ordinary metal-to-metal contacts and because of the current-carrying capacity of the mercury switch, or switches, is able to dispense with intervening relays and thus greatly increase the reliability of the total system.

The recording and controlling pyrometer is, of course, a combination of the two sets of mechanism above described.

Installing the Pyrometer. The point of importance is that, irrespective of type, the pyrometer is a sensitive millivoltmeter, but there is certainly no need to regard the modern pyrometer as a delicate instrument. To the contrary, it will be found to be remarkably robust and highly resistant to shock, damp and dirt. At the same time, as the highest sensitivity and precision in temperature measurement are demanded, this means that a highly sensitive instrument must be employed, and it is illogical to subject it to the effects of damp, dirt and fumes if, by care in making the installation, these effects can be avoided, however strong the resistance of the pyrometer to them may be.

Locations in relatively close proximity to running machinery or other sources of vibration, damp and dirty situations and fume contaminated atmospheres, should be avoided as far as may be possible. Where it is impossible to avoid vibration the instrument should be protected by mounting on rubber or felt bumpers, four usually being required. In extreme cases, spring mountings may be utilised in order that the vibration which would otherwise be transmitted to the instrument is dissipated. Apart from eliminating the effects of vibration on the pivots and jewels of the instrument movement, the disadvantage of a "dancing" pointer will be avoided. This condition makes an indicating pyrometer difficult to read, for the pointer is never completely at rest and tends to make the record of a recording pyrometer imperfect.

In all cases the pyrometer should be mounted at a point where the surrounding temperature is as near normal as possible, and the proximity of heating pipes, radiators and other sources of wide temperature variations, air currents, etc., should be avoided.

The instrument should be so mounted on the wall or panel that the scale and pointer are at average eye level in order that an accurate reading may be taken with ease. In this connection it may be noted that all indicating pyrometers are fitted with scale mirrors in order that parallax errors may be avoided and their proper use clearly demands that the instrument be approximately level with the eyes.

The mounting of a recording pyrometer requires more consideration than that of an indicator, for it is necessary to open the case to remove or replace the chart, wind the clock where this is of the mechanical type, and change or adjust the marking ribbon. Consequently, it is impossible to make the instrument so damp, dust- and fume-tight as the indicating pyrometer which is provided with a totally sealed casing. Furthermore, the paper chart may be affected by an excessively moist atmosphere and introduce troubles in running through its natural reaction. The most suitable location is in the office of the Shop Superintendent, where it can be kept free from adverse conditions. In many cases, the recorder is required as the basis of supervision and to provide a history sheet of the conduct of a particular operation. Where, however, the recorder is required for the purpose of regulation in addition, or—as in brickworks, etc.—a time-temperature curve previously drawn on the chart has to be followed by the operator, then it is desirable to provide a separate hardwood, glazed case to give additional protection.

The situation of an indicating control pyrometer will depend upon local circumstances, but be governed principally by the foregoing considerations. Such instruments are usually furnished with pilot lights indicating the opening and closing of the regulating switch contacts and if these are integral with the pyrometer, then the instrument must be so located that the lamps are within the convenient view of the responsible operative. Alternatively, the pilot lights may be separate and advanced to any desirable position—*e.g.*, at the front of the furnace.

(*To be continued.*)

The Sullivan Mine

The total tonnage mined at the Sullivan mine during the year 1934 was 1,748,401, comprising 1,745,992 tons of lead-zinc ore delivered to the concentrator at Kimberley, and 2,409 tons of crude lead ore consigned directly to the smelter at Trail. The total represents an increase of 335,023 tons over the figures for 1933. The concentrator treated 1,745,992 tons and produced 221,680 tons of lead concentrates and 192,552 tons of zinc concentrates. The fully developed ore reserves above the 3,900 ft. level were increased by 2,341,100 tons.

Study of Magnetism in U.S.S.R.

The importance of the magnetic properties of metals is becoming increasingly recognised and results from research in progress in Russia will have far-reaching effects.

THE magnetic core is the most important part of almost every electro-technical apparatus. The degree of efficiency of the telephone, transformer, electro-motor and magneto depend primarily upon the quality of the magnetic core. But the nature of the phenomenon which actually takes place on metals under magnetisation had, until recently, remained quite unknown. A French physicist in 1907 established the fact that iron crystals are able arbitrarily to magnetise themselves. However, this fact by no means disclosed the secret of the change in the main properties of a metal, that is, its form, electro - conductivity, heat conductivity, including its mechanical properties as a result of the magnetisation of its crystals.

In 1928 a young Soviet physicist, Nikolai Akulov, succeeded in establishing the fact that all the above changes in a magnetised metal are subordinate to one general law, and he gave this law its mathematical expression. By the use of the law one is now able to calculate all the basic properties of the magnetic metals, to establish a theory curve of magnetisation, and the curve or loop of hysteresis; to determine the variations in the phenomena under the influence of varied conditions, to ascertain the nature of the coercive forces responsible for the variations and the residual following demagnetisation.

The regularities of these phenomena and methods of their control had long been studied by physicists in England, Germany and America. By means of the law he formulated, a great amount of valuable work is being carried on by Professor Nikolai Akulov and his colleagues in the Physical Institute of the Moscow State University, in establishing experimentally methods of regulation of those obscure magnetic properties observed and studied by physicists of the above-mentioned countries, including such eminent scientists as Thomson, Noll, Curie and Nernst. As the result of this work it has been possible to study the principal ferro-magnetic properties of iron, nickel and their alloys.

The exceptional magnetic properties of iron and its alloys and compounds long ago attracted the attention of physicists, because its peculiar magnetic properties are not only of extraordinary theoretical interest but of great practical importance.

Professor Akulov and his associate workers have brought to light many new effects in metal crystals. They have made a careful study of the principal phenomena taking place in metals under formation. A series of methods have been worked out for the industrial control of the details of machines. As is well known the parts of electrical machines are subjected to magnetic influence when in operation, and it is desired to minimise this influence. In determining the crystal-lattice of a metal in relation to ascertaining its minute structure, physicists have commonly employed the Roentgen analysis. In the laboratory of Professor Akulov a method has been worked out by which the crystal structure of a metal may be determined without making a Roentgen analysis.

Some of the most recent achievements of the Akulov laboratory in the development of the theory of magnetic phenomena are as follows: a theory of anisotropy, known as the law of anisotropy, a theory of loss in hysteresis, a theory of even events, a theory of Theta E effect and a theory of the processes of magnetisation and the movement of magnetisation. This latter phenomenon is commonly associated with mountainous regions.

As present day industry is becoming more and more cognisant of the utilitarian importance of the magnetic properties of metals, it is likely that the accomplishments of Professor Akulov and his co-workers will have immediate and far-reaching value.

An Interesting Casting.

The accompanying illustration shows a steel casting 14 ft. 2 in. by 12 ft. 2 in. by 2 ft. 10 in., weighing about 24 tons. It is one of three cast in the Cammell Grimesthorpe Foundry of the English Steel Corporation, Ltd., to the order of Scriven and Co., Leeds, for a 750 ton press for use in South Africa. The casting is shown in the unmachined state, and it is interesting to note the large number of bolt slots which have been cored out on the face of the casting.

Quite a number of very interesting castings are at present being made in this foundry, we are informed, amongst them being the stern frames for the cruisers H.M.S. Sheffield and Newcastle, and large anvil blocks for drop hammers, one of which weighs about 100 tons.

Compressed Coke Gas as substitute for Gasoline.

INTENSIVE work is now being conducted by the Kharhov Society of Chemists of the U.S.S.R. to utilise compressed coke gas in automobiles instead of gasoline. A device for mixing gas with air to replace the carburettor of automobile engines has already been designed and built by the Ukrainian Automobile Research Institute.

Preliminary calculations have shown that the annual economy in Kharkov on fuel alone would amount to about 3·5 milliard roubles, since by using compressed coke gas the amount of gasoline required would diminish by over 4,000 tons. This innovation requires no alteration in the automobile engines.

Correspondence

Progress in the British Iron and Steel Industry.

Reference was made in our last issue to comprehensive schemes of reorganisation which have been put into operation during the last few years in the iron and steel industry, and to some of the revolutionary developments which have resulted. The object was primarily to refute statements, published from time to time, reflection on the progressiveness of the industry, and to show that at a time of great national adversity many iron and steel firms took great financial risks to install the most modern plant and equipment in order to place their works in a condition to meet changed industrial conditions. Schemes of reorganisation were put into operation some years ago by the majority of British firms and in many instances have now been completed or are nearing completion, with the result that the industry as a whole is in a condition of modernity, as regards plant and equipment, comparable with any other country.

It was impossible to make other than very brief references to the many schemes, but since the publication of the article in question we have received some correspondence dealing with recent developments of which the following is typical of the activities and developments in the industry :—

Recent Developments in Hadfield's Works.

The Editor, Metallurgia.

Sir,—A progressive attitude has always been adopted by us in regard to the development of new steels and new processes employed in manufacturing them. After the war we reconstructed a large section of our works to meet post-war needs. We constructed 11-in. and 14-in. rolling mills and a large 28-in. mill, equipped with the most modern type of heating plant and electrical means of operation. An additional large foundry was built with modern type of heating plant and electrical means of operation. An additional large foundry was built with modern equipment to produce the large arrears of orders for light castings needed to make good the wear and tear of the war years.

Since that time many economic changes have come over the world. Methods of engineering production have changed. Built-up constructions requiring the use of increased quantities of rolled products have developed to an amazing extent. At the same time other countries have developed their own steel works, and the character of the markets available for the sale of our products has gradually been changing.

To meet the situation brought about by these changes we have continually pursued a policy of adapting our plant to meet the needs of the times. We were one of the earliest organisations to adopt both the electric arc furnace and later the high-frequency electric process for the production of high-grade steels.

To cope with the demand for motor steels brought about by the imposition of import duties on foreign steel, we have recently extended the capacity of our rolling-mill plant. At the moment we have just completed the erection of a new large tilting open-hearth furnace, which is the only one of its kind in Sheffield. This furnace is equipped with the most modern features. The door jambs, ports and chill plates are water cooled, and the port ends are capable of being drawn back for access for rapid repair. The cooling system is mechanically operated, and the water supply is cooled in an atmospheric tower. The latest type of reversing valves, and the complete system of control instruments, both for air and gas flow, damper control and regenerator temperatures are installed.

A scheme of fuel economy has been adopted and the installation of waste-heat boilers, capable of raising a total production of 14,200 lb. of steam per hour at 180 lb. per sq. in. gauge pressure, and 170° F. superheat, has been completed. The surplus steam is used in a reciprocating steam-engine generator set, and the exhaust steam is utilised for operating mechanical stokers of the latest type. The operation of the producers, both on the air and on the steam supply, is automatically controlled.

At the present time in the 28-in. rolling mill a battery of the most modern type of reversing regenerative soaking pits, operated by producer gas, is being erected. In recent years, also, square turning lathes, planing machines and other devices for the production of the highest quality of rolled product have been provided. In the small mills the reheating and heat-treatment plant has been modernised by the adoption of mechanical stokers and the latest type of furnaces fired by coke-oven gas and automatically controlled.

A few years ago an extensive scheme of foundry reorganisation was undertaken. In this section of our production we have always had a high reputation for the quality of our products and in regard to the Hadfield manganese and other special steels our good name has been fully maintained. Where possible labour-saving devices have been introduced in the foundry ; and in the fettling shops considerable additions have been made to the pneumatic equipment in order to accelerate the cleaning operations conducted in these shops on the steel castings.

During recent years a separate section of the foundries served by a high-frequency melting unit has been developed which is devoted solely to the moulding of castings of special corrosion- and heat-resisting steels. The production of this class of steel represents one of the most outstanding metallurgical advances of the post-war period, and we have played a pioneer part in their development in this country.

In the machine shops modern machine tools are being installed to replace older types. These new additions include high-class grinding machines, large and small, suitable for grinding and finishing high-grade hardened steel rolls and articles requiring a high standard of accuracy and finish. A revolution has been made in the machine shops in the costs of machining due to the development of a tipped tool made of Hadfield super high-speed cutting alloy. The lower manufacturing costs and the speeding up of production generally are also matters that are most carefully watched, and in general more efficient methods have been adopted throughout the works.

The system of accounting and the methods of recording and compiling of financial cost and statistical data in operation by us are amongst the most advanced and up to date in the country. Our business ramifications throughout the world involve the maintenance of multifarious records, and the marshalling and presentation of statistical data relating to financial cost and commercial intelligence. A considerable amount of the work involved has been mechanised, and the fullest use is made of the latest types of office machinery.

The Hadfield Research Department, which has a record of over 50 years of scientific and metallurgical investigation, forms an important department of the firm. The laboratories are well equipped with the most modern apparatus, and staffed by men who are recognised experts in their particular branches. During the last 12 months the laboratories have been considerably extended for the purpose of additional experimental work in steel making and heat treatment. We were amongst the first in this country to install scientific control of heating plant by means of pyrometers, to set up an organisation for the prosecution of fuel economy, and to devote attention to the study and testing of refractories. Besides being continually occupied with devising improvements in the methods of scientific control of manufacture employed in the works and of the products at all stages down to the finished article, research is continuously going on towards the production of new types of steel to meet the special requirements of modern industry.—Yours, etc.,

Wm. A. Pickering, Director and Commercial Manager, Hadfields, Ltd.

East Hecla Works, Sheffield.

Use of Magnesium Alloys in Aircraft Construction

By E. PLAYER, Managing Director, Sterling Metals, Ltd.

Much of the advance in the use of aircraft is due to developments in light alloys, in which magnesium alloys are playing an increasingly important part. The extreme lightness of these alloys, together with their high relative strength, has made a great appeal to aircraft engineers, since it facilitates the production of maximum power with minimum weight. In this article the author deals more particularly with the developments of Elektron alloys.

THE rapid increase in development and use of aircraft for both civil and military purposes has greatly stimulated the evolution of light alloys of recent years. Great strides have been made with aluminium base alloys, both in wrought and cast form, and various compositions are now available which possess mechnical and/or corrosion-resisting properties which are a considerable advance on those available a few years ago.

The rather special fabricating technique necessary in the production of satisfactory castings, sheet, extrusions, etc., has now been well established, so that the magnesium alloys are now commercially available in the forms indicated.

The following notes refer specifically to the series of magnesium alloys known by the trade name of Elektron, with the development of which the writer has been intimately concerned during the past 13 years.

TABLE I.
CHEMICAL ANALYSIS.

Alloy Symbol.	D.T.D. Specification.	Supplied as	Aluminium, Maximum.	Zinc, Maximum.	Manganese, Maximum.	Magnesium, Approximate.	Impurities, Maximum.
A. 8	59	Sand castings, gravity die castings ..	8·0	1·5	0·4	90	0·50
A.Z. 31	136	Sand castings, gravity die castings ..	3·25	1·25	0·4	94	1·50
V. 1	136	Sand, gravity die, pressure die castings	10	3·5	0·4	86	0·50
A.M. 503	142 118	Extrusions .... Sheets	0·20	0·20	2·50	96	0·50
A.Z.M.	127	Extrusions	10	1·5	1	87	1·5
M.G. 5	—	Rivets and wire	95	—	—	5	0·5
A.Z. 855	—	Forgings	8·5 to 9	0·2 to 0·6	0·1 to 0·3	91	0·5

TABLE II.
THE MECHANICAL PROPERTIES OF ELEKTRON-MAGNESIUM ALLOYS.—CASTINGS.

Alloy Symbol.	Supplied in the Form of	Details of Test Bar.	Yield Point 0·2% Tons/sq. in.	Maximum Stress Tons/sq.in.	Elongation % on 2 in.	Reduction of Area %.	Maximum Compr. Strength Tons/sq.in.	Modulus of Elasticity Lb./sq. in.	Brinell Hardness.	Fatigue Range Tons/sq.in.
V. 1	Sand and Gravity die castings	Chill cast	7—8	11—14	4—8	5—6	19—21	$6{\cdot}5 \times 10^6$	65—70	5
V. I	Pressure die	Pressure cast	7—8	10—13	3—6	5	24	$6{\cdot}5 \times 10^6$	65—70	5
A. 8	Sand castings	Sand cast	6—7	9—11	3—5	7—10	23	$6{\cdot}5 \times 10^6$	45—55	3·5
A. 8	Die castings	Chill cast	6—7	13—15	6—10	10—14	24	$6{\cdot}5 \times 10^6$	50—60	3·5
A.Z. 31	Sand castings	Chill cast	4—5	11—13	6—9	7—10	19	$6{\cdot}0 \times 10^6$	35—45	3·5

It is self evident that, of all forms of transport, airborne machines are most dependent upon a high power-weight ratio. Consequently, any materials which possess a high strength-weight ratio such as the newer alloys referred to, are very attractive to the aeronautical designer and constructor. It thus follows that what may be called the youngest of the engineering constructional metals, magnesium, has aroused considerable interest amongst aero-engine and plane designers, by virtue of the low specific gravity of its useful alloys, which average about 1·81, as against aluminium alloys about 2·85. The fact that this low specific gravity is allied to excellent mechanical properties both in cast and wrought forms, renders the alloys of great value to the aeronautical engineer to-day.

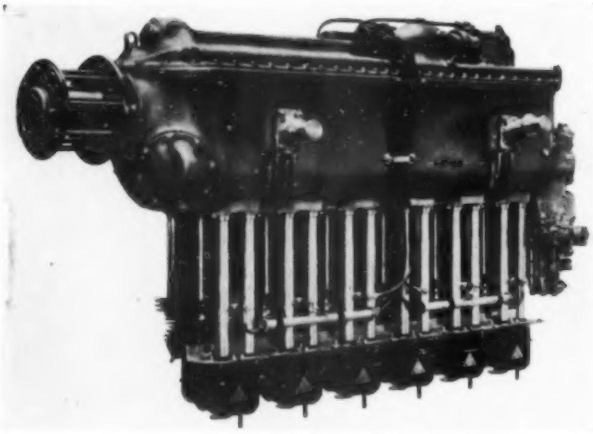
Composition of Alloys—Cast and Wrought.

Table I. gives the chemical composition of the cast and wrought alloys generally in use. It should be noted that the small amount of manganese present in all the alloys greatly improves their resistance to corrosion. Where these alloys are covered by an Air Ministry Specification the appropriate Specification number is shown in the second column.

Mechanical Properties.

Castings.—In Table II. are shown the mechanical properties which may be expected from chill and sand-cast test bars in the as-cast condition.

It will be observed that the mechanical properties of the



By courtesy of The de Havilland Aircraft Co., Ltd.

Fig. 1.—Gipsy Six 200-h.p. air-cooled inverted engine, in which Elektron castings by Sterling Metals Ltd., are used.

Elektron alloys are very similar in the as-cast form to most of the usual Aluminium alloys in similar condition. An exception is the modulus of elasticity. The disadvantage is more apparent than real, as in most cases considerations of practical production impose sectional thicknesses sufficient to render the modulus of secondary importance, and intelligent design of locally highly stressed sections will usually eliminate any risk of failure.

Heat-Treatment.—Considerable research and experiment has recently established a heat-treatment process which produces important improvements in the physical properties of sand castings, which in the *heat-treated* condition will show an increase in ultimate strength, fatigue resistance, elongation and impact value of from 40% to 50% above those obtainable in the as-cast condition.

A modified heat-treatment applied to the Alloy VI. sand-cast results in an increase in yield point of about 30% with some sacrifice in elongation, and an increase in Brinell hardness of about 40%.

It is extremely probable that most forms of Elektron magnesium alloys used in aero engine and airframe construction will, in the future, be called for in the heat-treated condition, in view of the exceptionally high strength-mass ratios thus obtainable, and of the fact that Elektron sand castings respond to heat-treatment more uniformly and to a greater extent than is usual with aluminium alloys.

Wrought Forms.—Table III. shows the mechanical properties of the various wrought forms of these magnesium alloys. Here again it will be seen that excellent mass-strength ratios are available in comparison with most other engineering materials.

Corrosion Resistance and Protective Coatings.

Magnesium alloys are more susceptible to attack by saline and acid reagents than are most aluminium alloys, and this effect is accentuated by electrolytic action set up at junctions between magnesium and metals strongly electro-negative to magnesium—for example, copper alloys. Direct attack is minimised by the use of high purity magnesium and by correct selection of the alloying metals.

Electrolytic action can usually be foreseen by the designer and the possibility avoided by correct designing. Corrosion under ordinary atmospheric exposure, whether damp or dry, is so infrequent as to be negligible, but as aircraft frequently travel oversea and in damp tropical climates, means of protection other than those touched upon are desirable.

Acid Chromate Pickle, by means of which Elektron cast and wrought parts are given a protective golden yellow chromate film, is one means of protection. An alternative form is the *Alkali Chromate Treatment*, developed by the Royal Aircraft Establishment, of which treatment there are several variants. The latter process has superior protective effect to the Acid Chromate Pickle, particularly against sea-water attack. It has the additional advantage that one modification of the R.E.A. treatment allows fully-machined parts to be treated as a final operation without affecting machined dimensions.

Both Acid Chromate and R.A.E. treatments form excellent bases for the application of further protective pigments such as cellulose enamels.

Most cast or wrought aero-engine and air frame components are finished by prior treatment with one or other of the baths mentioned, followed by a finishing coat of a suitable enamel. So protected, little trouble has been

TABLE III.

THE MECHANICAL PROPERTIES OF ELEKTRON ALLOYS.

EXTRUDED RODS, BARS AND SECTIONS; SHEETS AND STRIPS; FORGINGS.

Alloy Symbol	Supplied in the form of	Condition of Test Bar.	Proof Stress 0·1% Tons/sq.in.	Maximum Stress Tons/sq.in.	Elongation % on 2 in.	Reduction of Area %.	Maximum Compression Strength.	Modulus of Elasticity Lb./sq. in.	Brinell Hardness.	Fatigue Range Tons/sq.in.	Maximum Shear Stress Tons/sq.in.
A.Z.M.	Rods, bars, sections	As extruded	8—14	18—20	20—10	23—28	23—25	$6·5 \times 10^5$	55—60	8	10
A.M.503	Rods, bars, sections	As extruded	7—9	12—17	10—3	30—25	18—22	$6·0 \times 10^6$	40—50	6	8
A.M.503	Sheet	Annealed	6—8	12—15	10—7	20	18—20	$6·0 \times 10^6$	40	5	8
A.Z. 855	Forgings	As forged	9—14	18—24	15—8	10—15	24—28	$6·5 \times 10^6$	65—75	8	10

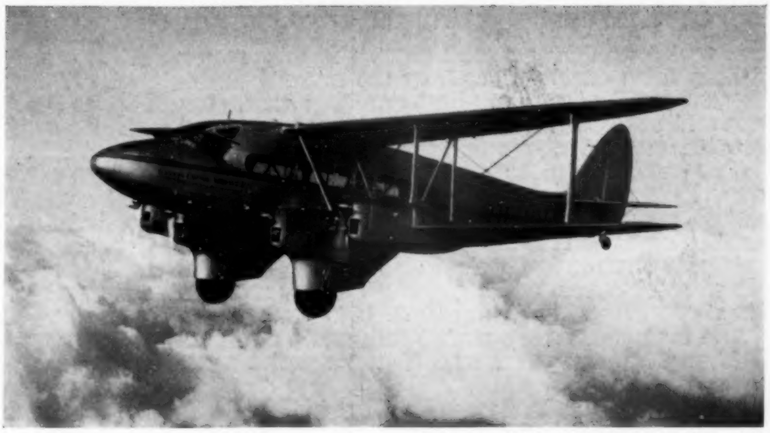
Fig. 2.—Bristol Pegasus engine. Another example in which Elektron castings are used.

By courtesy of Bristol Aeroplane Co., Ltd.

experienced from corrosion under widely varying conditions. It should be noted that all the processes mentioned are patented.

Applications—Castings.

Engines.—Naturally engine construction calls for the largest use of castings in the aircraft industry. For highly-stressed castings, engine crankcases may be taken as typical examples. For straight-line engines, magnesium alloy crankcases are used in considerable numbers. Fig. 1 illustrates a De Havilland Gipsy VI. engine in which such castings are used. This type of engine is used increasingly for civil aircraft carrying up to 12 to 16 passengers, and, in a slightly modified form, was used in the D. H. Comets which put up such a wonderful performance in the recent England-Australia air race. Other components embodied in this and similar types of engine for which Elektron is the standard material are timing gear covers, induction pipes, top covers, bearing caps, etc.



By courtesy of The de Havilland Aircraft Co., Ltd.

Fig. 4.—A de Havilland DH86 Express Air Liner in which Elektron magnesium sheet by James Booth and Co., Ltd., is used.

Prolonged service experience has shown the eminent suitability of the magnesium alloys mentioned for engine construction, where due regard has been paid to the special physical characteristics of the material, and enthusiasm has been tempered by cautions.

Radial type engines also employ a considerable number of magnesium base castings, though in this case the crankcase, in all but the smaller sizes, is an aluminium alloy forging. In the larger sizes, the crankcase component is so highly stressed that castings, either in aluminium or magnesium alloys, are not sufficiently reliable.

Fig. 2 shows a Bristol Pegasus engine. Elektron-magnesium alloy castings are used in this engine assembly for blower casing, rear cover and gearcase, inlet-pipe branches, rocker covers, etc.

It may be remarked that, as one of the problems of the aero-engine builder is to secure rigidity of his components without overweighting his engine, it is becoming recognised as an advantage to be satisfied with a weight-saving per casting of between 20% and 30%, as compared with aluminium, instead of the theoretically possible 40%. By increasing thicknesses where excessive vibration or breathing is likely to occur, greater rigidity is secured allied with the weight reduction indicated—a desirable combination.

Air Frames.—Apart from engines, Elektron-magnesium castings are employed regularly for numerous air-frame and landing-gear components. Examples are control wheels, tail wheel forks and landing wheels. The last mentioned instance represents one of the most important developments in the use of magnesium alloys, and a very high percentage of modern machines is fitted with landing wheels the bodies of which are magnesium castings. These range from airliner types taking tyres 5 feet outside diameter down to light plane wheels carrying tyres 20 in. outside diameter. A representative group of Dunlop landing wheels ready for tyre fitting is shown in Fig. 3. The castings are Elektron-magnesium A.8 Alloy.

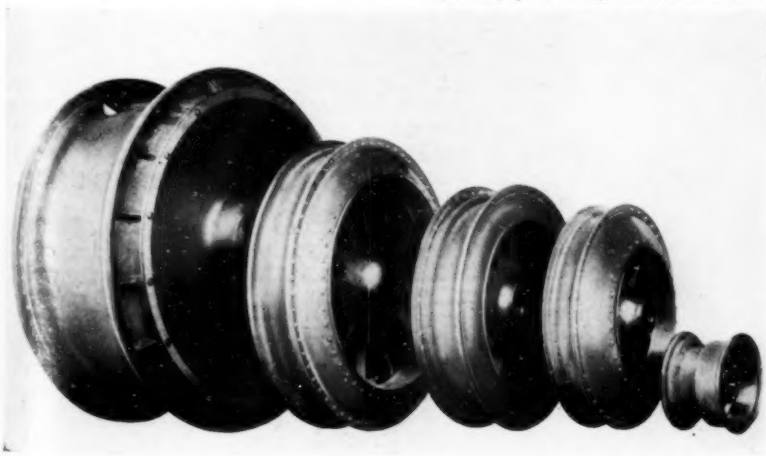
One advantage of the cast wheel is that the brake drum forms an integral part of the wheel body casting, this system conferring great rigidity to the steel-brakeliner, and avoiding the numerous stressed joints inevitable in a purely sheet or composite sheet and wire spoke construction, involving riveted or welded joints.

General.—The successful use of any engineering material depends as much on full knowledge and recognition of its limitations as on its valuable characteristics. This attitude of mind has been maintained in the application of magnesium alloy castings in aero-engine and airframe construction and design. Thus it is that no attempt has been made to employ magnesium alloys for air-cooled cylinder heads or pistons, or for parts in constant contact with water, such as water-cooled cylinder heads.

In the case first mentioned, the alloys are unsuitable for the reason that, in the present state of knowledge, no magnesium base alloy is available which will retain strength and hardness at a sufficiently high level when subject to the high temperatures at which cylinder heads and pistons must function.

Fig. 3.—Aircraft landing wheels in Elektron magnesium castings are used.

By courtesy of The Dunlop Rim & Wheel Co., Ltd.



In the second case, although satisfactory inhibiting reagents may be employed in water-circulating systems, it is not possible to guarantee that these will always be added under service conditions when replenishing the water supply. For a similar reason, parts subject to frequent immersion in sea water are unsatisfactory in magnesium alloys, and are usually best made in a corrosion-resisting aluminium alloy.

Wrought Alloys.

The range of wrought alloys and the physical properties thereof are shown in Tables 1 and 3 preceding.

The use of the wrought forms of Elektron-magnesium alloys in aircraft construction, whilst of slower growth than that of castings, is now increasing rapidly, and the following notes give a

general idea of scope of use and development. Generally speaking, wrought Elektron has entered into airframe construction via lightly stressed parts, this very proper attitude being established both by the material manufacturers and the designers. Such gratifying success has been achieved that there is little doubt that the extended use of the material will proceed apace.

Sheet and Strip Applications.—In the form of sheet and strip, Elektron is largely used in building the skin of aircraft, and particularly those parts which need to be carefully streamlined in order to reduce drag and frontal resistance. Thus engine, fuselage, undercarriage, main and tail wing fillets, etc., are largely made of this material. The alloy used for these purposes is A.M.503, for the reason that it is the most easily worked and welded of all the Elektron alloys, and possesses the highest corrosion resistance.

It has usually displaced pure aluminium in the applications mentioned, and as it is 33% lighter and nearly 50% stronger than that metal, it will be seen that considerable weight reductions are effected, with consequent improvements in flying efficiency and economy. In view of the much higher strength of Elektron A.M.503, as compared with aluminium, a weight saving considerably more than the

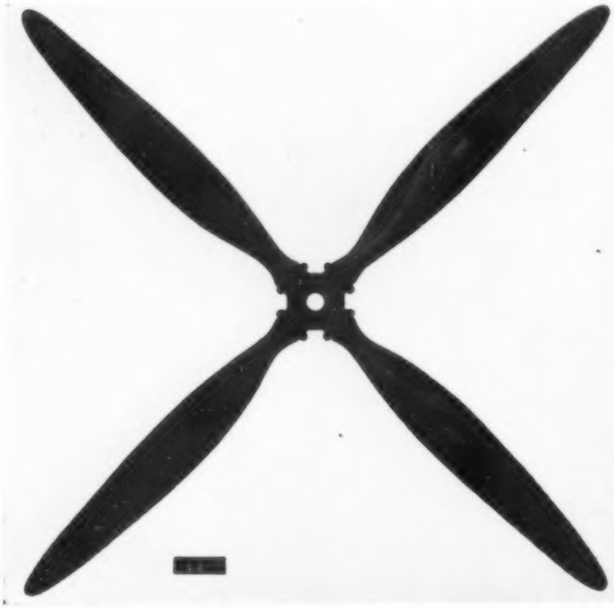


Fig. 5.—Forged Elektron airscrew by James Booth and Co., Ltd.

33% mentioned can be effected in many places by taking advantage of the higher mechanical properties indicated, full details of which are given in Table 3.

Elektron sheet cannot be worked cold except for the smallest deformations, and this disadvantage as compared with aluminium has retarded the development of the material in this country. At temperatures between 270° C. and 320° C., however, it is amenable to all the usual processes of the tinsmith ; and, if properly handled, the hot-working technique costs little more than cold working. Fuel and oil tanks are instances where great weight reductions can usually be made by using magnesium alloys, but, owing to the difficulties of cold working, little progress has been made in this country. On the Continent, however, fuel and oil tanks in Elektron are commonly used, and now that the hot-working technique is becoming more familiar, it appears likely that similar developments will occur here.

A further difficulty with fuel tanks is the slight corrosion set up on magnesium alloys by traces of water in the fuel.

This difficulty has been overcome on the Continent by providing a special sump wherein the water is collected by gravity, and by immersing in the fuel itself a capsule of reagent that absorbs any water which may be present, without affecting the fuel.

The illustration Fig. 4 shows a De Havilland D.H.86 Express Air Liner, which employs Elektron sheet, strip, etc., for cowlings. The power units for these machines comprise four Gypsy VI. engines, and in these Elektron castings enter largely as crankcases, filter bodies, etc.

These machines have an unusually high pay-load capacity in relation to their cruising speed and engine power. This high efficiency has been secured largely by the weight saving made possible by the intelligent use of magnesium alloy castings, sheet, etc., in engines and airframe.

Joining.—Elektron is readily welded by means of the oxyacetylene flame and the use of suitable flux. Such welds, made by a properly trained welder, are uniform in structure, and free from inclusions which might set up corrosion. Welds are afterwards beaten or rolled to break up the zone of transition from the cast structure of the weld itself to the pure wrought structure about ¼ in. either side the junction line. So treated, welds show a tensile strength at right angles to the line of weld of from 80% to 90% the strength of the unwelded sheet. As welded, without subsequent treatment, the strength is 50% to 60% that of the sheet.

The famous De Havilland Comets have engine, undercarriage, wing and tail cowlings in Elektron A.M.503, and are mentioned here because the complexity of design and exquisite workmanship of some of these parts indicate the facility with which the material can now be welded and shaped.

Where welded joints are not convenient or desirable, rivets may be and are employed. For this purpose an alloy known as M.G.5 is used, composition and properties of which are shown in Tables I. and III. This alloy, it will be seen, possesses the necessary high tensile and shear strength figures, and, eqully important, has an electro-potential approximating to that of magnesium. For this reason, the risk of corrosion at riveted joints in Elektron sheet is negligible.

Sections and Tubes.—Parts comprising the skin and fairings of airframes are usually braced with extruded tubes or sections. Where these bracings must be welded to the frame, the alloy A.M.503 is employed, but where riveting is the method of joining, the tubes and sections are made in alloy A.Z.M. Details of composition and properties are as Tables I. and III.

Interior furniture for aircraft, such as chairs, tables, handrails, etc., is now extensively built up of light-gauge magnesium alloy tubing and sections. This method of construction produces extraordinarily light but strong articles and finds increasing favour.

Forgings.—Forgings and pressings are used for the production of various machined parts used on aero-engines, and where very high strengths are not necessary, the alloy A.Z.M. is employed. By far the most interesting and important development of Elektron forgings, however, is in the manufacture of airscrews. It is generally recognised that the adjustable or variable pitch propeller confers a very considerable improvement in the all-round flying efficiency of an aeroplane. Hitherto, such propellers have been made in aluminium forged alloys, as so far it has not been found possible to employ wooden blades in this form of assembly.

Some of the advantages of the variable or adjustable pitch propeller are lost, however, as a consequence of the considerable increase in nose weight imposed by the weight of the operating mechanism, and the increased weight of aluminium compared with wood. It thus follows that magnesium offers the ideal material, providing the alloy possesses sufficient strength, as, being all metal, it can be used for the variable pitch type construction, where wood cannot, and being 40% lighter than aluminium, the increased weight incurred by using the latter metal is largely counteracted.

The following figures, which are actual data obtained from propeller forgings produced under commercial conditions, show that the Elektron-magnesium alloy A.Z. 855, which is used for propeller-blade manufacture, possesses mechanical properties which make it eminently suitable for the purpose.

Direction.	0·1% Proof Stress. Tons/sq. in.	Ultimate Strength. Tons/sq. in.	Elongation %.
Longitudinal	12—16	18—19	9—12
Transverse	—	14—16	—

The above test figures are taken from blade forgings 7 ft. to 9 ft. long with butt 6 in. to 7 in. diameter, producing finished airscrews from 12 ft. to 13 ft. 6 in. diameter.

Over the past three years, 20 to 30 Elektron forged airscrews have been in use on service machines, coupled to engines of every standard type developing 500 to 600 h.p. at 1,000 to 1,110 r.p.m. These airscrews have proved an unqualified success, and no single failure has occurred which is attributable to defective material or inadequate mechanical properties. Where Elektron blades are used with variable or adjustable pitch propellers, a saving in gross weight of the finished assembly of from 20% to 30% may be expected as compared with the use of aluminium blades, and this without any commensurate sacrifice of mechanical properties.

It may be added that the Elektron forged propellers are in general use on the Continent for high-power machines, and in view of the very considerable weight of large propellers, particularly with adjusting gear, the very material mass reduction avaiable by the use of magnesium alloys indicates an extended use in this country.

In conclusion, it is hoped that this brief review of the development of magnesium alloys in aircraft construction may serve as a slight tribute to the metallurgists, engineers and technicians whose patient and quiet work has produced such substantial results in a comparatively short time.

The Pretoria Steel Works, South Africa

Installation of blast-furnace gas cleaning plant.

The principle of this plant is based on the combined work of Sir Oliver Lodge, Dr. Cottrell and Dr. Moller.

GREAT interest attaches to the new steelworks at Pretoria of the South African Iron and Steel Industrial Corporation, which has involved a capital outlay of over £5,000,000, mostly provided by the Union Government. The normal production is 150,000 tons of steel per annum, and included is a blast-furnace of 500 tons of pig iron per 24 hours capacity along with a by-product coke-oven plant of 57 ovens for the production of 450 tons of coke per 24 hours, using a blend of 25% Natal coal and 75% Transvaal coal. Also there are two steel-melting furnaces, one steel mixer, and heavy and light rolling mills, in addition to sheet mills, the iron ore used being a local Pretoria product (48% Fe) which is blended with high grade Rustonberg hematite (68% Fe) from the Transvaal, the rated performance being 17 cwt. of coke per ton of pig iron.

For the cleaning of the blast-furnace gas a "Lodge-Cottrell" electrostatic plant on the latest two-stage principle is installed, cleaning down to much lower than the ordinary gas engine standard of 0·0088 grains of dust per cubic foot. In general the plant comprising a pre-cooler, three main dry electrostatic treaters, three slat cooling tower, and three wet electrostatic treaters, along with the necessary fans, valves, pipes, sludge pumps for the settling ponds,transformer house, and other accessories. This is generally on the same lines as the "Lodge-Cottrell" electrostatic cleaning plant just recently put into operation at the Tata Works, Jamshedpur, and that just completed at the Corby Works for Stewarts and Lloyds, Ltd. In this latter connection, it may be stated that a further unit has recently been ordered to bring up the total capacity to 8,000,000 cubic feet feet of gas per hour.

The results already obtained as regards cleaning of the blast-furnace gas at Pretoria have surpassed expectations and repeated analysis of large samples of the gas (360 cubic feet and upwards) show no trace of ore dust. Thus the amount of soluble material caught by the filter of the testing apparatus averages 0·0004 grains per cubic foot, or less than one-tenth of the guarantee (0·004 grains per cubic foot).

It will be remembered that on the two-stage principle of cleaning the hot blast-furnace gas at about 450° F. is treated in the first stage of the electrostatic plant, when about 97 to 98% of the total dust is removed in the dry state. On the usual lines the gas passes through chambers containing vertical earthed collector plates and discharge electrodes connected to high tension current supply at

General view of the Pretoria iron and steel works, showing the electrostatic gas-cleaning plant at the centre.

60,000 to 70,000 volts, stepped up from ordinary low tension supply in a special transformer and converted to direct current by motor-driven rectifiers. The dust particles are ionised and repelled to the collector chambers, which are provided with rapping hammers to discharge the accumulated material. In the second stage all the suspended moisture and the remaining 2 to 3% of the total dust is removed, and the final cleaned blast-furnace gas is dry, cold (about 75° F.) and dust-free, generally containing as low as 0·002 grains of dust per cubic foot, or even below this figure as at Pretoria—well below the usual guarantee of 0·004 grains. Gas with this extreme degree of cleanliness is, of course, suitable for any purpose, including modern close packing for the stoves, and general combustion using the latest designs of complete automatic burner control gear.

Reviews of Current Literature.

Corrosion Committee—Third Report.

As in the case of the First and Second Reports, the Third Report of the Corrosion Committee is published as an Iron and Steel Institute Special Report. It is in five sections, the first of which deals with the constitution of the Committee. The second section describes the field tests on atmospheric corrosion. It is noteworthy that an additional corrosion station has been set up at Sheffield University, where tensile test-pieces, prepared from large specimens of the mild steels and irons have been exposed. Further specimens of high-tensile structural steels, chiefly of the copper-chromium type, have been prepared for tests, and the Report gives preliminary details of the experimental programme concerned.

Data of a semi-quantitative type on the descaling of the various as-rolled specimens on exposure to weathering continue to accumulate. It has been found that in the case of materials rolled according to normal works practice, the rolling scales on British wrought iron and on ingot iron are more resistant to weathering than those on mild steel. The presence of copper, both in mild steel and Swedish iron, was found to reduce the rate of corrosion considerably; in the case of steel there was no difference between specimens containing 0·2 and 0·5% of copper, respectively. Other quantitative results for the rate of corrosion of mild steel have been obtained, and the most practical method for removing rust from the specimens after exposure has been investigated. It has been decided to do this by pickling in dilute sulphuric acid in the presence of an inhibitor.

Analyses of the rain-water collected at the four main experimental stations are given, and the losses in weight of the small control specimens of ingot iron and of zinc at most of the corrosion stations, in some cases for several single periods of one year's exposure, are tabulated and discussed. Observations on the painted stands confirm the conclusion already drawn that the priming coat on structural steelwork should be of an inhibitive character. Tests have been commenced at Sheffield in which the steelwork of the stands was prepared in various surface conditions prior to painting; some additional paints have been included in these tests.

The results of experiments on the corrosion of steel sleepers under actual service conditions are described.

The third section concerns marine corrosion and describes the progress of the tests on steel plates built into a barge. Inspection has given some indication that mild-steel plates finished at a reduced rolling temperature, as a result of discontinuous rolling, shed their scale in the shipyard rather more rapidly than plates rolled under normal works conditions. It was found at inspections of the barge whilst in commission that most of the corrosion observed had been initiated by mechanical damage. This rendered it difficult to compare the merits of the plates prepared in different surface conditions prior to the initial painting. Plates that had been painted whilst hot on the mill floor were in better condition than the other when the finishing coat applied at the yard was bituminous paint, but in cases where the finishing coat was red oxide paint the whole paint film showed a curious and unexplained tendency to peel off the plate.

Examinations of the steel pontoons supporting a floating landing stage are reported by R. H. Myers. Some of the plates showed pronounced pitting, and it was concluded that the trouble probably originated several years ago when an interval of seven years occurred between successive applications of protective coatings. It is probable that three, or at most four, years is the maximum advisable interval between successive "re-conditionings."

Tests on welded specimens of ships' plate, both of ordinary and of high-tensile *D* quality steel, conducted by H.M. Admiralty, are reported. The specimens were exposed to various types of marine conditions for 30 months. The conclusion reached was that, on the whole, corrosion troubles should not be aggravated by welding, provided that the process is correctly carried out.

The fourth section gives the preliminary results of an investigation on metallurgical factors influencing the corrosion of iron and steel. Those of tests on the scale-covered materials exposed in the main researches of the Committee are of especial interest in that they show that, whilst the corrosion probability is generally determined by the physical character of the rolling scale for the materials as tested, it was definitely less for the wrought irons and the ingot iron than for the mild steels.

The systematic tests on totally-immersed ferrous materials conducted under standardised experimental conditions are described. The influence of various factors, such as the diameter of the vessel and the depth of immersion are fully discussed; the standard method of testing is described, and suggestions are made for simplified forms of tests. An investigation on the effect of manufacture and composition on the corrosion rates of ordinary iron and steel has shown that, under the particular experimental conditions, these factors are relatively unimportant as compared with environmental factors, although there is some indication that wrought iron corrodes less rapidly than steel.

Experiments are reported, the results of which give further support to the conclusion that the application of paint to specimens from which the scale has been partly removed by weathering yields much less satisfactory results than when the paint is applied to specimens either with an intact scale or totally descaled by weathering or by other methods. The same authors find that, on the whole, the orders of merit in atmospheric exposure tests of painted and unpainted specimens of different materials are similar but not identical.

Further corrosion tests are given in detail on ferrous wires, undertaken to elucidate the ageing of hard-drawn mild-steel wire, and the results of several inspections of painted specimens at Birmingham and Farnborough.

The ageing tests showed a definite increase of 3·7% in the tensile strength of a hard-drawn 0·22% carbon-steel wire that had suffered a reduction in area of 24%: with a reduction in area of about 75% no definite variation in breaking load could be detected. The Birmingham paint tests confirm the value of pickling specimens prior to painting.

The fifth section includes the results of investigations by the Committee on the corrosion of steel sleepers in mines. It was found that in dry pits no trouble is experienced from corrosion. Details are given of the inspection of two old ferrous structures—a wrought-iron rail laid in 1832, and the old cast-iron bridge erected at Coalbrookdale in 1779.

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Nickel Exports.

Exports of nickel by the International Nickel Company of Canada are stated to have reached $5,265,696 during the first two months of 1935, as compared with $4,406,673 for the same period last year. January exports were valued at $2,560,249, as compared with $2,782,682 in 1934, but February exports rose from $1,623,991 to $2,705,387.

We understand that the new shaft at the Creighton mine of this Company has reached a depth of 600 ft., and steady progress is being made in sinking operations. The shaft and necessary surface plants ared esigned to develop economically the lower levels of the mine, and the total cost is estimated at $2,700,000.

Combined Wire Drawing and Heading Equipment used in Bolt Making

In this article is described a method of converting a wire rod directly into a finished bolt which is claimed to be advantageous to a bolt and nut plant not large enough to maintain a wire-drawing plant.

DRAWING wire and manufacturing bolts in continuous combined operations with a wire drawer that is attached to a cold-heading machine, and which draws and coats the wire and feeds in into the header intermittently as it is needed, is a recent development in the bolt-manufacturing industry. The wire-drawing machine is operated by power supplied from the header. Combination units of wire blocks and double-stroke cold bolt-heading machines are being used in American plants, and have resulted in marked economies in making bolts. This method of converting a wire rod directly into a finished bolt is claimed to be of particular advantage to a bolt and nut plant that is not large enough to maintain a wire-drawing plant.

The wire drawer is set directly in front of the bolt header, and the die is moved back and forth along the wire rod, instead of having a stationary die and pulling the rod through the die to draw it down to size. The wire-drawing equipment is extremely simple in operation. The stock is fed into the heading machine by the regular feed rolls in the usual manner. During the periods between the feeds the wire is held securely by grips, and the drawing die is pushed back along the rod a distance equal to the amount fed. When the feed occurs, the grips release and the drawing die and the slide, which carries it, move forward with the rod, being pushed back again during the next stationary period. The slide which carries the drawing die is of box shape at the top, and is filled with drawing and coating lubricant, which simultaneously coats the stock for cold heading and extruding operations.

Motion is imparted to the drawing die by a vertical lever fulcrumed in the draw frame beneath the slide, which in turn derives its motion through a long horizontal connecting rod located under the header from an adjustable crankpin at the back of the heading machine. This pin is on the end of a crankshaft, mounted in an independent housing rigidly connected to the front drawer frame by spacer bolts, and is driven by chain and sprocket from the crankshaft of the header. The stroke of the mechanism that actuates the die slide is adjustable, so that in each cycle the length of the wire that is drawn is the length of the bolt that is being headed, plus enough material to make the head. The wire is drawn during the idle time of the header on the return stroke of the cross-head, when the machine requires a reduced amount of power, so that there is no appreciable increase in power required because of the addition of the wire-drawing equipment. The standard headers with which the blocks are equipped are driven by the same motors that were used before the wire blocks were attached.

For starting the end of new coils of rod, an "inching" feed is provided. This starting mechanism consists of an auxiliary grip and a feed slide with a short stroke hooked up to and operating from the vertical lever. The feed slide pushes the rod forward one to three inches at a time, and the auxiliary grips hold it during the drawing until the main drawer grips and the feed rolls of the header are reached, when the operation is resumed. The use of the "inching" feed makes the pointing or swaging of the rod unnecessary, except for $\frac{3}{4}$ in. and smaller sizes, before it goes into the heading dies.

The coil of wire rod is set in front of the wire drawer, and as the material is straightened in going through the block, wire enters the header perfectly straight. In addition the heat generated in drawing is claimed to be sufficient to cause the material to flow more easily in the header dies, and to prolong the life of these dies. Another factor which tends to extend the life of the header dies is that the freshly drawn wire is clean, while wire that has been kept in storage bins becomes dirty and often collects emery dust which is hard on the dies. A set of tungsten carbide dies has been used in one of the bolt headers since the wire block was attached to the machine over a year ago, and is still in good condition. Another advantage claimed for the use of this wire-drawing equipment is that because successive coils are drawn through the same die, there is no variation in diameter of the wire produced.

Considerable saving in production costs, particularly in raw material, has been effected by the company drawing wire and heading bolts with the combined equipment. The saving in cost of wire rods as compared with wire is about 75s. per ton for plain steel and much higher for alloy steels. The amount of inventory has been reduced one third, the number of sizes carried in stock has been cut down and the floor space required for raw stock has been reduced 50%. The cost of drawing the wire as an entirely separate wire-drawing operation, estimated at 16s. to 20s. per ton, has been elim nated. A rod of one size is now used for making wire in two or three sizes, and instead of carrying 15 sizes of wire in stock the stock now consists of nine sizes of rods. Formerly wire of 150-ft. coils was used, but these have been replaced by coils of wire rods weighing 350 lb., so that the stock is started into the header at less than half the former frequency, thus saving time. The only increase in floor space that is required is about four feet at the front of each header that is taken up by the wire block. Wire in plain carbon steel is drawn in diameters from $\frac{7}{32}$ in. to $\frac{5}{8}$ in., the size being controlled by the capacity of the header. Drafts are usually held to ·025 in. to ·030 in., although a reduction as high as ·090 in. has been achieved on this wire block. The wire-drawing machine described, which is designated the Hogue wire drawer, is now being built and placed on the market under an exclusive licence by the Ajax Coy, which makes the machine in standard sizes from No. 0 to No. 4 inclusive, for drawing $\frac{1}{4}$ in. to $\frac{7}{8}$ in. diameter rods.

Institute of British Foundrymen.

The Thirty-second Annual Conference of the above Institute will be held in Sheffield on July 2–5. In view of the unique part played by the Sheffield district in the development of the iron and steel industries, it is apparent from the programme arranged, that every effort has been made to render the occasion a memorable one. Papers of a high technical standard will be presented and discussed, and visits to important works in the Sheffield district have been arranged.

The first Edward Williams Lecture will be given by Sir William J. Larke, K.B.E., his subject being "Man and Metal." At the technical sessions the following papers will be presented :—"Refractories for Foundry Use," by W. J. Rees, M.Sc. ; "Sand Problems in a Brass Foundry," by F. Howitt ; "Steel Castings," by W. H. Hatfield, F.R.S., D.Met. ; "Research on Steel Castings," by Prof. J. H. Andrews, D.Sc. ; "A note on the Influence of Temperature Gradients in the Production of Steel Castings," by George A. Batty ; "Castings," by W. Machin and M. C. Oldham ; "Some Notes on Ingot Moulds," by T. Swinden, D.Met. and G. R. Bolsover, F.Inst.P. ; "The Making of Large Castings by Loam Moulding," by Henri Fabre ; "German Iron Foundry Progress in Piston Rings, Brake Drums, and other Automobile Castings," by William A. Geisler ; and "Relationship in Cast-Iron Test Results," by G. L. Harback.

Moscow Institute of Mineral Resources.

Among the recent achievements of the Institute of Mineral Resources in Moscow is the prospecting of rich deposits of fluorite, used for optical purposes. These deposits are declared to be remarkably rich in crystals.

The work of the Institute embraces prospecting, mineralogy and the making of tests for the purpose of supplying factories and plants with methods of utilising minerals. The Institute has made many valuable discoveries in various fields. It has prospected valuable deposits of arsenic and of rock crystal in the Verkhnaya Ryech District in the Caucasus. Sulphur has been obtained from waste gases of copper-smelting plants and two large plants are now operating on these principles.

The Institute recently developed an original method of obtaining alumina, used in the manufacture of aluminium, until now obtained chiefly from bauxite by treating alunite with lye. The new method makes possible the use of a new source of raw material, the deposits of which in the Garjinski District, Azberjain, are estimated at many millions of tons. An experimental plant producing alumina, the first of its kind in the world, has been constructed in this district.

By producing artificial defibrating stones from Soviet raw materials the Institute is estimated to have saved the country three million gold roubles during the Second Five Year Plan. These stones used in the paper industry were imported until recently. The Institute has also organised the production of slate boards to replace expensive marble used for electro-technical purposes. A method of dry concentration of kaolin has been developed which is of great value in certain districts of the Ukraine, where a serious shortage of water for technical purposes exists.

A new method of chemical analysis of rock shortens the process considerably. Estimates of iron deposits in the Ural Province have increased by 25% as the result of prospecting and technological study of titano-magnetic ores. Researches establish the possibility of using these ores for industrial purposes by extracting titanium and vanadium from them.

Deposits of acid-resisting asbestos have been located in the Urals, and this dispenses with the need for importing this product from Rhodesia, hitherto regarded as the only source of supply. It is expected that the U.S.S.R. will now be in a position to export this product to Europe.

The Institute has also carried on extensive work in the field of non-ferrous and light metals. It has aided in establishing a number of new branches of mining industries in the U.S.S.R., such as slate, graphite, sulphur and others.

Use of the Pipette Method in the Fineness Test of Moulding Sand.

The determination of fineness is one of the most important tests made on a moulding sand. The permeability, strength, refractoriness, and moisture required for tempering the sand, as well as the surface finish obtained on castings made in the sand, to a large degree depend upon the size distribution of the constituent particles. In the method for classification adopted as a standard by the American Foundrymen's Association the particles of a moulding sand are classed in two groups by means of a sedimentation method, the larger particles being termed "grain material," and the smaller particles, "clay substance." A sample of moulding sand is dispersed in distilled water and allowed to settle. Clay substance is the portion which settles at a rate less than 1 in./min. The faster settling material constitutes the grain and is further classified by a series of sieves, the finest being a No. 270 sieve. The portion of the grain which passes through a No. 270 sieve and still settles at a rate faster than 1 in./min. in distilled water, is called "pan material" or "silt."

In view of recent developments in the methods for measurement of subsieve particle sizes, it was felt that improvement in the method for sizing the particles of moulding sands was desirable. After a preliminary study of the available methods, the pipette method was selected as being the most suitable for this particular use. No great difficulty is encountered in sizing the larger particles by the use of sieves, but for particles finer than 50 microns in diameter other methods must be employed. The pipette method has been satisfactorily used in analysis of particle sizes of soils. Details of the development and use of the pipette method in the fineness test of moulding sands are outlined in a paper by Clarence E. Jackson and C. M. Saeger, Jr., which is published as Research Paper RP757 by the U.S. Bureau of Standards. The method of computation and scope of results are shown by typical examples. A rapid method suitable for foundry control work and routine testing is suggested. The authors state that the equipment required is easily assembled, the operation is simple, the time required for a determination is short, the information obtained is wider in scope, and the reproducibility of results is greater than is obtained by other methods now in use.

Noranda Mines, Ltd., Annual Report for 1934.

According to the annual report of Noranda Mines, Ltd., for the year ended December 31, 1934, a large increase in ore reserves was attained during the twelve months, notwithstanding the record tonnage removed. There is now indicated above the 2,725-ft. level, 6,826,000 tons of sulphide ore over 4% copper, containing 7·25% copper, and 0·166 oz. of gold per ton ; 20,497,000 tons of sulphide ore under 4% copper, containing 1·04% of copper and 0·191 oz. of gold per ton ; together with 982,000 tons of siliceous fluxing ore, containing 0·15% of copper and 0·142 oz. of gold per ton. These figures represent an increase of 4,868,000 tons of sulphide ore over last year's figures, notwithstanding the removal during the year of approximately 1,390,000 tons of the two classes of sulphide ore. This means that some 6,258,000 tons of new sulphide ore were developed, or put in sight last year, of which approximately 2,425,000 tons were from the "upper H" ore body above the 1,225-ft. level, and the smaller outlying ore bodies. The increased price of gold, together with decreased operating costs, has permitted the inclusion of material formerly considered low grade. In the circumstances, the available tonnage of ore is sufficient to keep the plants operating for 18 years.

During the year the smelter treated 1,050,684 tons of ore, concentrate and refinery slag, from which 70,607,764 of anodes were produced, the average analysis of which was 99·39% copper, 7·04 oz. of gold per ton, and 15·66 oz. of silver per ton. The concentrator treated 920,363 tons of ore from the Horne mine, the average assay of which was 2·34% copper, 0·125 oz. of gold per ton, and 0·32 oz. of silver per ton, from which 181,938 tons of concentrate were produced for smelting. The concentrator's daily capacity was increased in April, 1934, from 2,000 to 3,000 tons daily, and at the same time a tailing re-treatment plant was placed in commission to effect the saving of gold formerly lost. A 100-ton experimental cyanide unit was placed in operation last June to extract additional gold from the pyrite residue of the re-treated mill tailing, and a new 500-ton cyanide mill is now under construction and expected to be ready for operation in April.

Selenium is now being produced in substantial tonnage by the company's subsidiary, Canadian Copper Refiners, Ltd., at Montreal East, and it is expected that tellurium will be produced some time this year.

We are asked to draw attention to the fact that many features of the bright annealing furnace mentioned in the account of the above Works, published in our last issue, are the subject of patents or patent applications for cracking and partial burning of butane, and the chain screens for preventing undue loss of protective gas.

Recent Developments in Materials, Tools and Equipment

Hiduminium Alloy Tubes and Sections.

A completely new works equipped with modern plant for the manufucture of high duty aluminium alloy tubes, rods and extruded sections.

IN the modern world the uses of metal tubes and sections are so nearly endless that further opportunities for their employment are found almost every day. In addition to general applications, their use has been developed in materials having a high strength-weight ratio, and it is quite natural that aluminium alloys should command consideration in this respect. In order to be in a position to meet this demand, Messrs. Reynolds Tube Co., Ltd., who have had many years of experience in the manufacture of high quality steel tubing, have built a completely new works and plant in which aluminium alloy tubes, rods, and extruded sections are made.

The choice of a suitable aluminium alloy, according to *The Nickel Bulletin*, was naturally of the utmost importance owing to the necessity for maintaining the same high quality which exists in the case of steel tubing. After exhaustive tests, the well-known Hiduminium group of aluminium alloys was selected in view of the extensive success which has been achieved by its use in recent years in both the aero-engine and automobile fields, and in particular it was decided to specialise in "R.R. 56," which is the most suitable in the group for wrought forms.

A typical chemical composition of this alloy is as follows :—

	%
Copper	2·00
Nickel	1·30
Magnesium	0·80
Iron	1·40
Titanium	0·10
Silicon	0·70
Aluminium	Remainder

Tubes made from the above alloy are covered by the Air Ministry Specifications D.T.D. 220 and extruded sections by the British Standards Specifications L. 40 (in course of preparation). The following table gives particulars of the mechanical properties required by those specifications :—

	D.T.D. 220 Tubes.	L.40. Extruded Bars and Sections Fully Heat-treated.
Proof stress (0·1%), tons per sq. in.	22 min.	20 min.
Maximum stress, tons per sq. in.	27 min.	27 min.
Elongation, %	—	12 min.

The general physical properties of "R.R. 56" are :—

Specific gravity	2·75
Young's modulus, lb. per sq. in.	10,500,000
Coefficient of linear expansion per ° C.	0·0000224

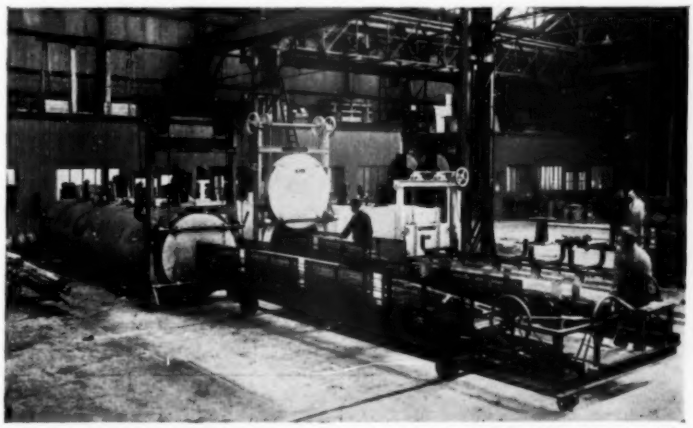
It will be noted from the above specifications that in the extruded condition quite good mechanical properties can be obtained, but by the use of suitable heat-treatment tensile strengths equivalent to those possessed by mild steel can be obtained.

The heat-treatment consists of two operations, the first being known as the "solution" or "quenching" treatment, in which the material is heated to 520–535° C. and quenched in water. The second operation consists of the "precipitation" or "ageing treatment"—*i.e.*, heating to 165–175° C. for 10–20 hours, followed by cooling in air.

This type of heat-treatment has several important advantages since it is the latter operation which produces the final high-tensile condition. The first heat-treatment leaves the material in a medium tensile condition and having relatively good ductility; for example, with "R.R. 56" after the first operation the maximum stress will be approximately 20 tons per sq. in., and the elongation approximately 20%.

Since, therefore, the material after the first quenching is in more or less an annealed state, it can easily be cold-formed and then can be hardened by the relatively simple second operation, which, because of the low temperature at which it occurs, avoids any risk of distortion. Moreover, "R.R. 56" does not "age harden" to any extent at ordinary room temperature after the quenching treatment, consequently forming operations need not be carried out immediately after the quenching. For example, those manufacturers who do not wish to instal the necessary quenching furnace equipment can obtain their material in the quenched form, carry out the necessary manipulation, and then "age harden" it.

The tubes and extruded sections can be supplied in great variety to suit all requirements. Whilst this alloy possesses corrosion resistance equal to that of similar alloys, it can be supplied in the anodically treated condition, which takes the form of a hard adherent film providing excellent corrosion resistance. In connection with the anodic treatment, it may be noted that the film can be dyed with various colours and finishes.



By courtesy of Reynold's Tube Co., Ltd.

Automatically-controlled, electrical annealing furnaces, mechanical charger and ageing furnace at Reynolds Tube Company, Ltd., Birmingham.

The applications of the tubes and extruded shapes are too numerous to mention, but passing reference can be made to the construction of aeroplanes; bus, tram and railway carriage bodies; elevators and mine cages; machinery which is subjected to high velocity reciprocating motion, and also to high centrifugal forces.

The excellent equipment of the works themselves consists of the latest electrically operated heat-treatment and annealing furnaces which are automatically controlled so that all the operations from the preheating of the billets for extrusion to the final precipitation treatment of the finished article are carried out under ideal conditions, thus enabling a high standard of quality to be uniformly maintained from batch to batch.

According to official reports, the Soviet gold industry programme was fulfilled by 100·6 per cent. during the first five months of the present year. A trust, Azcherzoloto, has been formed for prospecting the newly discovered gold deposits in the basin of the River Sochi, in the Caucasus. The first nuggets found weighed from one to five grammes and had an admixture of platinum.

"K" Monel Metal.

For many years Monel Metal has been studied with a view to further improving its known high properties; this has resulted in the recent development of "K" Monel Metal the outstanding properties of which are described in this article.

USERS of metals have long been familiar with the valuable properties of the alloy known as Monel metal, which ranks as one of the most reliable materials. The outstanding features that render this alloy of great commercial value are high resistance to corrosion and high tensile strength. It possesses great resistance to various corroding media, such as salt water, atmospheric attack, dilute acid, etc., and has the remarkable property of resisting, to a very marked degree, the deterioration in strength, to which the majority of non-ferrous metals are subject, from use at temperatures above the normal. For many years investigations have been in progress on this alloy in an effort to further improve its properties, with the result that a superior form of monel metal has been developed, which, after simple heat-treatment, according to *The Nickel Bulletin*, possesses mechanical properties comparable with those of alloy steels.

This new form of alloy, obtained by the addition of aluminium and careful adjustment of the composition, is known as "K" Monel Metal. It is non-magnetic under ordinary working conditions and remains so at sub-normal temperatures. This quality is particularly valuable in instrument, aircraft and radio work. For example, in aircraft, non-magnetic corrosion-resisting wire of high strength is needed. Some materials though non-magnetic in the soft condition, become magnetic after being cold-worked to develop higher strengths; the non-magnetic quality of this alloy however, is retained in the fully hardened condition.

The material is available in three different conditions:—(*a*) as hot-rolled and softened; (*b*) as hot-rolled, softened and thermally hardened; (*c*) cold-worked and thermally hardened.

The latter condition, whereby thermal hardening is superimposed on "cold-worked" hardness, gives the greatest degree of hardness and the highest ultimate strength.

Typical properties for these three conditions are shown in the following table.:—

Condition.	Ultimate Strength. Tons/sq. in.	Yield Point. Tons/sq. in.	Elongation % on 2 in.	Izod. Ft./lb.	Brinell.
Hot-rolled and softened	39	19	35	100	140
Hot-rolled softened and thermally hardened	60	43	30	70	270
Cold-worked and thermally hardened	72	60	15	50	320

Tests show that in the fully heat-treated condition this alloy will carry an alternating stress of 17½ tons per sq. inch for 10,000,000 reversals without fracture. Its strength at elevated temperatures, determined by short-time tensile tests, of cold drawn and heat-treated rod, is shown in the following table:—

Temperature °C.	Maximum Stress. Tons/sq. in.	Yield Point. Tons/sq. in.	Proportionality Limit. Tons/sq. in.	Elongation % on 2 in.	Reduction in Area %
25	73·6	55·8	46·9	21·0	38·9
95	72·8	55·4	46·4	21·0	37·0
205	69·6	52·7	44·	20·0	35·0
315	65·9	48·5	37·56	19·5	32·8
425	55·8	47·3	36·3	18·5	29·8
540	55·6	45·9	31·5	9·5	9·8

As yet, full determinations of creep strength have not been carried out, but the following results will give some idea of the behaviour of this alloy under prolonged stress. Specimens of rod which had been cold-worked and heat-treated to give a Brinell hardness of 285, sustained a load of 30 tons per square inch at 400° C. for three weeks without showing any measurable creep. In the case of fully heat-treated rod having a Brinell hardness of 240, which had not been cold-worked, a load of 20 tons per square inch was sustained for three weeks without showing any measurable creep.

Heat-Treatment

To soften "K" Monel Metal it should be heated to a temperature of approximately 800° C. for a sufficient time to ensure complete soaking, and quenched in water or oil. To harden, the material should be reheated to a temperature of 590° C. and slowly cooled. The degree of hardness developed varies to some extent with the time of exposure at this temperature. Four hours is generally sufficiently long to develop practically full hardness, but slightly increased hardness results from holding at this temperature for six or eight hours. The hardening treatment can be be applied to softened, hot-rolled or cold-worked material.

In the soft condition, as will be noted in a foregoing table, it has a hardness of approximately 140 to 150 Brinell. By heat-treatment alone, this hardness can be increased to over 260 Brinell, while by a combination of cold work and heat-treatment hardnesses of 320 Brinell or more may be obtained.

In the softened condition or moderately hardened (up to 270 Brinell) can be machined at almost the same speeds and feed as for mild steel, provided good quality high-speed steel tools are used. In the work-hardened plus thermally hardened condition (Brinell 280/330 or even higher) Widia or similar tools are usually necessary but this can be avoided by machining before final thermal hardening.

Applications.

The uses of this alloy are essentially those which demand high strength and/or hardness combined with high corrosion resistance or immunity from rusting. Typical examples which may be cited are: valves and seats in pumps handling oil containing brines and sodium sulphide (here "K" Monel has outlasted high alloy corrosion-resisting steels with a service life of 4 to 1 in its favour), valves and seats on "starting-air" bottles for Diesel engines, blades for paper-making machinery, and impulse blading of steam turbines, operating at high pressures and superheats.

As already mentioned, its "non-magnetic" high strength qualities make it suitable for aircraft, istrument or radio work, where corrosion resistance, coupled with high strength or hardness, is essential for parts which must be non-magnetic.

This alloy is available as hot-rolled or cold-drawn rod, wire, forgings and turbine blade profiles, and the production of these is already established. Other commercial forms will be added as occasion demands. Further information on this alloy is obtainable from the suppliers Messrs. Henry Wiggin and Co., Ltd., Birmingham.

Society of Chemical Industry.

The Fifty-fourth Annual Meeting of the above Society will be held in Glasgow on July 1–6. A very comprehensive programme has been arranged which in addition to the business includes many interesting functions and visits to works in the district. The President, Mr. Edwin Thompson, J.P., will deliver an address on "National Water Supplies" and several papers will be presented at technical sessions, including: "Some Problems in Chemical Engineering which arise in H.M. Navy," by Commander J. L. Bedale, R.N.; and "How Food is Transported by Land and Sea," by Brig.-Gen. Sir Harold Hartley, C.B.E.; and A. J. M. Smith, Ph.D., M.A. The Medal of the Society will be presented to E. F. Armstrong, Ph.D., D.Sc., L.L.D., F.R.S., who will deliver an address, "The Past, the Present and the Future."

Some Recent Inventions

The date given at the end of an abridgement is the date of the acceptance of the complete Specification. Copies of Specifications may be obtained at the Patent Office, Sale Branch, 25, Southampton Buildinsg, London, W.C. 2, at 1/- each.

Gas Producing for Furnaces for Heat Treating.

A GAS, for use as a heat treatment atmosphere in metal-heating furnaces, having a substantial nitrogen content and of an oxidizing, reducing, carbonizing or decarbonizing character, is produced by mixing hydrocarbon gas or vapour with air in proportions selected according to the

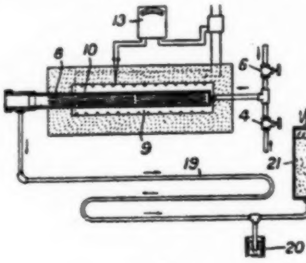


Fig. 1.

required character of the gas, and reacting the mixture with the assistance of applied heat. As shown in Fig. 1, gas and air are supplied under control of valves 4, 6 to a tube 8 containing a catalyst 10 and heated externally by resisters 9 controlled from a recording pyrometer 13. From the tube the gas passes to the furnace through a cooler 19 with a moisture trap 20, and a drier 21. When using a natural gas containing 84% methane, 14% ethane, and 2% nitrogen the reaction chamber is maintained at a temperature of 1,850° F., and the gas is mixed with air in proportions up to ten parts by volume of air to one part of gas. Various air to gas ratios are given for producing atmospheres suitable for particular purposes—*e.g.*, in converting low-carbon steel, a 4 to 1 ratio would be used, producing a gas containing 25% hydrogen, 1% methane, 15% carbon monoxide, 3% carbon dioxide, and the remainder nitrogen. Higher air to gas ratios would be used for decarbonising steel, or annealing copper, and lower for steels with a higher carbon content, or for carburising. If butane is used, three times the quantity of air may be employed as compared with natural gas. In general, heat treatment gases may be produced containing 7—37% hydrogen, up to 10% methane, 35—80% nitrogen, 5—22% carbon monoxide and up to 10% carbon dioxide.

The Specification as open to inspection under Section 91, describes a heat-treatment furnace having aligned heating and cooling chambers, end elevator charging and discharging shafts, and a pusher at the charging end for transferring the goods from the elevator to a driven roller-way extending through the heating and cooling-chambers. The cooling-chamber is separated from the heating-chamber by a door, and has inlet and outlet passages for the atmosphere gas. This subject-matter does not appear in the Specification as accepted.

419,832. ELECTRIC FURNACE Co., Salem, Ohio, U.S.A. [Class 51 (ii).]

Rotary Furnaces.

MUCH development has been effected during recent years in rotary or semi-rotary melting furnaces; a more recent development of this character is shown in the accompanying illustrations. As will be noted in Fig. 1, this design of furnace has one end in the form of a semi-circle, and a burner nozzle 4 is so arranged that the flame is directed on the upper part of the curved surface and an outlet flue 5 is provided at the burner end. The burner may be fitted, as shown in Fig. 1, at an inclination in a stationary block 3 mounted centrally in the end of the furnace, or may deliver through a flared central opening. Alternatively the burner may be offset from the axis of the furnace, and may deliver either through an end opening, or as shown in Fig. 5, through an inclined passage 38 at the side of the feed opening 12. The outlet flue may be central or there may be a pair of outlet flues 22 one on each side of the burner opening. In the construction of Fig. 1, the outlet flue is above the burner opening so that the outgoing gases will cross the flame, and the external extension 6 is cranked downwards so that it terminates coaxially with the furnace and opposite the inlet opening 7*a* of a recuperator 7. In a modification, Fig. 6, the burner port 49 and outlet flue 51

FIG. 5.

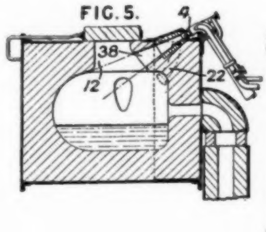


FIG. 1.

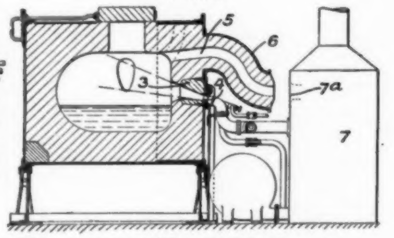
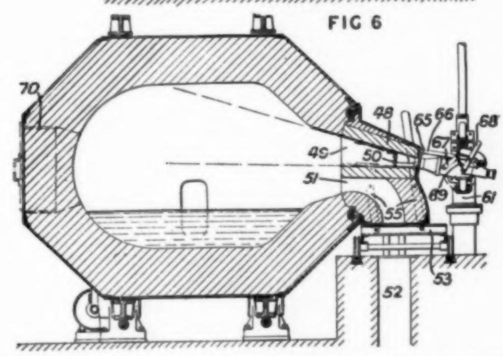


FIG 6



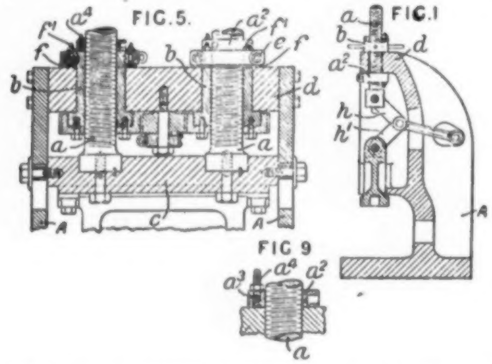
are formed in a block 48 mounted by four parallel arms 55 on a traversing carriage 53. The carriage is positioned by a stop on the rails, and carries a plate which covers the flue 52 when the block is moved clear of the furnace. The burner together with its supply piping is mounted to swivel about a vertical axis and is locked to the block by a latch 66 which engages behind a catch 65 on the block. The latch is operated by the hand-lever 68, and is caused to rise clear of the catch by the link 67. A spring 69 holds the latch in the locked position. Charging may be effected through a door 70 at the hemispherical end of the furnace, and the burner block may be positioned in the waste gas outlet port, so that it is surrounded by the outgoing gases. Specifications 401,629 and 402,712 are referred to.

400,956. W. F. WILTSHIRE, King's Norton, Birmingham. [Classes 51 (i) and 51 (ii).]

Metal-working Presses.

IN a press having a ram operated through a toggle linkage and adjustable by threaded elements associated with the bridge of the press, a threaded rod *a* supported in an aperture in a bridge piece *d* by an internally threaded collar *b* is clamped and locked in its adjusted position by a spring-controlled device which as shown consists of a two-part ring a^2 apertured near its periphery to receive screws a^4, Fig. 9, which hold springs a^3 under compression against the collar *v* to prevent rotation thereof. A second ring a^2 engages the underside of the bridge *d*. The rod *a* may be rotatable in threads formed directly in the bridge *d* or in a bush therein or the bush may be rotatable and the rod be held against rotation. At its lower end, the rod *a* is either

integral with or secured to a cross head c guided in the press frame A by a bolt c^2 passing through the crosshead and slots in the frame and edge plates h, h^1 at the ends of the crosshead constitute the toggle linkage. For a wider ram, two or more threaded rods a, Fig. 5, are secured to a crosshead c and pass through rotatable bushes b to which they are clamped by a ring a^2 after adjustment. The bushes b are geared together for simultaneous movement and are

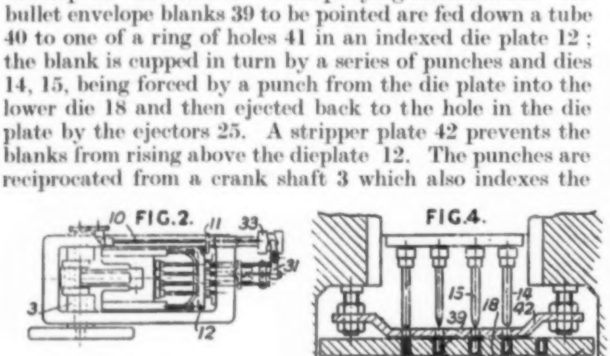


supported by a grooved two part collar e provided with adjusting screws f^1 engaging a revolvable ring f on the bridge d.

414,690. F. HUMPHRIS, Park Road, Parkstone, Dorset. [Class 83 (iv).]

Stamping Bullet Envelopes

A RECENT development in stamping machines for bullet envelopes is shown in the accompanying illustrations. The bullet envelope blanks 39 to be pointed are fed down a tube 40 to one of a ring of holes 41 in an indexed die plate 12; the blank is cupped in turn by a series of punches and dies 14, 15, being forced by a punch from the die plate into the lower die 18 and then ejected back to the hole in the die plate by the ejectors 25. A stripper plate 42 prevents the blanks from rising above the dieplate 12. The punches are reciprocated from a crank shaft 3 which also indexes the

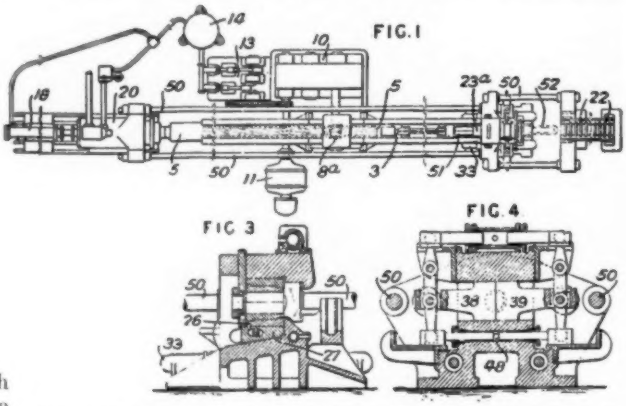


die plate through a side shaft 10 and Geneva gear 11. The shaft 10 also operates the ejectors through a cam 33 and lever 31. A weight 38 and levers 34 apply a thrust to the bushes 22, etc., to yield in case of jamming.

421,851. GREENWOOD AND BATLEY, LTD., Albion Works, and J. C. M. MACLAGAN, Roundhay, both in Leeds.

A Tube-making Device

IN making tubular metal bottles by forcing a mandrel partly through a billet and then removing the closed end of the billet container so that the mandrel can push the billet through a series of ring dies to reduce it, the heated billet 51 is placed in a hopper 23a and pushed into the special container by the mandrel 3, operated by hydraulic cylinder 18. Fluid pressure cylinder 33 then advances the wedge 27 to raise the bottom half 26 of the container against the billet. Fluid pressure cylinder 20 then forces the mandrel 3 into the billet until near its bottom end. The end halves 38, 39 of the container are then slid aside by fluid pressure cylinders 48, and the lower half 26 is dropped. The electric motor 11 is then started to drive the mandrel rack 5 forward so that the mandrel and bottle 52 is passed through the reducing die rings 22. The speed of the rack 5 and its pinion 8a is determined by the gear box 10. The motor 11



drives the hydraulic pump 13 supplying the air-hydraulic accumulator 14 for the various cylinders. The rods 50 take the longitudinal thrust. Specification 300,288 [Class 83 (iv)], is referred to.

421,992. WELLMAN SEAVER ROLLING MILL CO., LTD., and S. SMITH, Victoria Street, London. [Classes 83 (ii) and 83 (iv).]

Cleaning and Coating Metals

WIRE, tubes, rods, etc., are drawn by a process comprising heating the article to be drawn in a reducing atmosphere, coating with lead, and then drawing without intermediate annealing. The process is especially applicable to nickel alloys containing chromium, copper, manganese, aluminium, etc. The temperature of heat-treatment preferably lies between 650°–1,200° C., and the reducing atmosphere should be free from moisture and oxidising gases such as carbon dioxide, and have a relatively high concentration of hydrogen. An alloy containing 14% of chromium and 80% of nickel, with iron, may be heated in a hydrogen-containing atmosphere at 1,065° C. for 9 mins., at 980° C. for 12 mins., or at 1,150° C. for 6 mins. A rod of the alloy, sold under the Registered Trade Mark, "Monel," may be heated at 925° C. in a natural-gas atmosphere containing 3·5% of carbon monoxide. An alloy containing 30% of nickel, 62% of iron, and 8% of chromium may be heated at 1,065° C. The lead coating may be applied, using a bath of flux floating on a bath of molten lead, which may contain impurities such as antimony, the wire being passed through the flux and into the lead and then out of the bath at a point which is free from flux. A flux contains 8 parts by volume of zinc chloride, 4 parts of sodium chloride, and 1 part of ammonium chloride. The lead may be maintained at a temperature of about 370°–425° C., and preferably at 380°–400° C. Wire strands may be passed through a wiper to remove excess lead. Coils of wire after being rolled over in the bath are thrown on the floor and shaken to prevent sticking.

416,236. MOND NICKEL AND CO., LTD., Thames House, Millbank, London.

Base Metals Mining Corporation, Ltd., report the shipment of 1,133·73 long dry tons of zinc concentrates, assaying 61·12% zinc to Europe on February 13, and despatch of 849·49 long dry tons of lead concentrates, assaying 80·7% lead and 10·05 oz. of silver per ton. Milling operations have ceased temporarily.

Business Notes and News

Iron and Steel Industry of Japan

According to the report of the British Commercial Counsellor at Tokio, the Japanese iron and steel industry is rapidly becoming one of that country's major industries. Although its output is still small by comparison with other countries, at the end of 1934 production was nearly equal to consumption. It is noteworthy that production is still insufficient as regards special steels. Certain plates, sheets, and rods and other semi-products, and hoops are not made in Japan. It should be remembered that the steel industry has to contend with fundamental difficulties in the form of inadequate supplies in Japanese territory of high-grade ores and coking coal.

India has been one of the main sources of Japan's supply of pig-iron, but last year Soviet Russia supplied 40,000 tons of this product and is contemplating further important sales this year. Tin plates, hot-rolled hoops, and wire rods were the largest items in the imports last year of finished steel products. Steel works are being enlarged with the object of supplying the Far-Eastern markets. Tin plate manufacture is being increased and plants installed for producing hoops and plates.

Scientific Management Conference

Next month the Central Hall, Westminster, will become a world "Parliament" House in which business men and women from 40 nations will meet to discuss problems which affect world trade and industry. It will be the biggest gathering of business folk which has ever been held in this country, for 2,000 delegates from Great Britain and all parts of the world are expected to be present.

The event is the sixth annual Conference for Scientific Management. It is to be opened by the Prince of Wales. It will be the first time that the congress has come to England. The delegates, of whom about 300 will be women, will pool their expert knowledge in an international endeavour to free world trade and industry from some of the ills besetting it at the present time. Already more than 200 papers prepared by experts on a host of important topics have been submitted, but no time will be spent in reading them in session. They will be circulated in printed form to the delegates and will form the basis of the discussions.

Two special trains are to take some of the delegates on a tour of works of the country after the Congress, visiting, among other places, Manchester, Huddersfield, Sheffield, Nottingham, Northampton, Bristol, Birmingham, Liverpool, Glasgow, Edinburgh, York and Leeds. These special trains will be in effect travelling hotels for delegates will dine and sleep on board during a week of touring.

More Work for Steel Trade

Another step towards the recovery of the steel industry and the absorption of many more workers has just been taken. This step is the signing by the new Steel Cartel agreement which had been reached at Luxembourg. By this agreement the British Iron and Steel Federation become members of the Steel Cartel. Under this agreement, to which France, Germany Belgium, Luxembourg and Great Britain are now parties, only 670,000 tons of steel will be allowed to come into Great Britain during the 12 months from August next. After that period the arrangement will be revised in the light of Great Britain's productivity capacity. The agreement is for five years and since imports of steel from the Continent have usually been very high –2,800,000 tons in 1931 and even with a tariff on imported steel 1,400,000 tons was imported last year– it should make a substantial contribution to the recovery of British ndustry.

For the first time the British iron and steel industry takes its place as a member of the International Steel Cartel as a friend and ally and this will be of great importance not only towards the better organisation of the iron and steel industries of the world and the provision of cheap steel to world consumers with the expansion of many new industries and markets, but should also assist in no small degree towards the standardisation of world prices and currencies and the policy of peaceful co-operation between all countries and the restoration of international prosperity.

Electric Furnace Installation

Messrs. Holman Bros., Ltd., of Camborne, manufacturers of pneumatic rock drills and tools, are reorganising their heat-treatment plant. At present both fuel-fired and electric furnaces are employed, but the former are about to be replaced, and we understand an order has been placed with Birmingham Electric Furnaces, Ltd., for nine modern "Birlec" automatically controlled electric furnaces. When this installation has been accomplished Messrs. Holman's claim that in all carburising, reheating, tool hardening and tempering, the highest obtainable degree of accuracy, uniformity and consistency will be assured.

Contracts in South America

South America has recently provided British industry with two contracts of outstanding interest, and in each case acknowledgment is made of the help derived from British official action. One is the contract awarded to the Metropolitan-Vickers Electrical Company for the electrification of certain portions of the Brazilian railway system at a total cost of £3,000,000. It includes the supply of transformers, transmission line material, sub-station plant, trolley line equipment, multiple-unit trains and electric locomotives. The sub-contractors for the overhead equipment—covering about 112 single track miles—transmission lines to sub-stations, and all rail bonding are British Insulated Cables, Limited. The other outstanding order—namely, for oil-well casing and other tubular requirements to the total value of about £250,000—is stated to be a direct consequence of the Anglo-Argentine trade agreement. It has been obtained by Stewarts and Lloyds Limited, and the British Mannesmann Tube Company Limited, acting in collaboration.

Tin Problems in America

A Bill has been introduced in the United States Senate which proposes to prohibit the export of tin plate scrap and to impose an import duty on imported metallic tin of 6 cents per pound. One object of the measure is to provide a means of making the country less dependent on foreign sources for supplies of tin and other strategic materials during war time, the tax being suggested as a means of establishing a domestic smelting industry. At present tin imported into the United States is smelted in Great Britain. It is asserted by the promoters of the Bill that the United States is now entirely dependent on foreign sources for supplies of tin. Amongst the principal tin ore producing countries are Great Britain, France, and Belgium. The conservation of domestic tin plate scrap is necessary to provide materials for the detinning plants of the country.

Personal.

Mr. Fred Clements has been appointed to a seat on the Board of Directors of the Park Gate Iron and Steel Co., Ltd., of Rotherham. Mr. Clements, who has held positions of increasing responsibility with the Company during the last 30 years, has been the General Manager since 1923, an office he will continue to occupy.

Mr. Clements enjoys an international reputation in the Iron and Steel Industry as an authority on a number of the major aspects of metallurgical activity. His book on "Blast-Furnace Practice" is deemed a standard work and his papers before the Iron and Steel Institute have had a wide influence on the subsequent development of the Industry throughout the world.

Mr. Clements is a Member of the Institution of Civil Engineers and also of the Institution of Mechanical Engineers. He is a Member of the Association of Iron and Steel Electrical Engineers of Pittsburg, U.S.A., and an Associate Member of the Institution of Electrical Engineers in Great Britain. He has been for some years a Member of Council of the Iron and Steel Institute, and is a member of the Iron and Steel Industrial Research Council of the British Iron and Steel Federation, being the Chairman of the Blast-Furnace Research Committee of that organisation.

The development of the Works of the Park Gate Iron and Steel Co., Ltd., to a level which makes them one of the "show" places in the Industry in this country is a reflection of the influence Mr. Clements has exerted.

Canada's Active Mineral Exploration Programme

The Hon. W. A. Gordon, M.P., Minister of Mines of Canada, recently introduced in the House of Commons at Ottawa a vote providing for the necessary expenditure in connection with geological surveys during the coming summer season under the auspices of the Dominion Department of Mines.

The Department proposes to send out 180 surveying parties to examine and report on mineral areas, concentrating upon those believed to hold out prospects for the discovery of gold. It is estimated that the field costs for each party would average $4,000, in addition to which there would be charges in connection with the preparation of reports and maps, the total expenditure anticipated being about $1,000,000. The parties will be in charge of trained geologists, and their work will be entirely investigational and not for the purposes of trying to locate and stake economic deposits.

In introducing the vote the Minister explained that the distribution of reports by members of the geological survey invariably preceded an advance of prospectors searching for minerals in areas indicated by the surveys as being favourable for the discovery or ores. The Minister produced some remarkable figures showing the extension of the gold mining industry since 1928, in which year the number of milling plants operating was 30, whilst it had risen to 115 last year, as compared with only 64 in 1933 and 40 in 1932. He stated that this industry offers an outlet for many of the young men of Canada, and believes the organisation of these geological parties will start a work which will be of benefit to the prospectors and bring about an even greater increase in gold mills.

The parties are to be sent to every province except Prince Edward Island, as well as to the Northwest Territories and to the Yukon Territory; indeed to wherever conditions appear favourable for the possible deposition of gold ore. The exact number of parties which will go into each Province has not yet been determined, but there will be approximately 12 parties in Nova Scotia; 4 in New Brunswick; upwards of 15 in Quebec and 30 in Ontario; approximately 20 in northern Manitoba; 40 in Saskatchewan; 8 in Alberta; 20 in British Columbia; 10 in Northwest Territories and 5 in Yukon Territory. The localities in which the parties will work has not yet been definitely determined, and it will not be possible to complete the work this year, as the surveyors' field notes will have to be transcribed and published after the parties return in the autumn.

Copies of the various reports of the Geological Survey of Canada are available in the Reference Library, Canada House, Trafalgar Square, London, S.W., from the inauguration of the Survey many years before Confederation; and most of the more recent reports can be consulted on demand at Canada House by persons interested.

Catalogues and Other Publications.

The English Steel Corporation, Ltd., Vickers Works, Sheffield, have issued a new Summary of Standard Steels, Part 3, which gives compositions, treatments, and mechanical tests of a number of the important alloy steels they manufacture. This summary is in the form of a chart and should be valuable for reference purposes, particularly in the drawing office. Copies are available on application.

For more than half a century the Fraser and Chalmers Engineering Works of The General Electric Co., Ltd., at Erith, has manufactured mining and milling plant of every type, for export to all parts of the world. Throughout this period the design and construction of the various machines have been continually improved with the result that they now embody many features of great practical value. Much of this plant is described in an interested brochure recently issued by this Company, copies of which are available from Fraser and Chalmers Engineering Works, Erith, Kent, England.

A copy of the latest edition of the handbook issued by Appleby-Frodingham Steel Co., Ltd., an associated company of the United Steel Companies, Ltd., has been received. The wide variety of information contained in its 360 pages is of such a comprehensive and useful character as to place the book amongst those of real value to the structural and engineering trades. The book contains many British Standards of various types of structural steel, together with much technical information, formulæ, tables, etc., which makes it of special value to the structural designer and draughtsman. It is well bound, admirably printed, and is invaluable as a reference book on plates, rolled sections, colliery materials, special sections, stanchions and struts, solid round columns, slab bases, beams and girders, etc., since it not only gives profiles, dimensions, etc., but the properties and safe loads of parts for structural purposes.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£100 0 0

ANTIMONY.

English		£77 0 0
Chinese		69 0 0
Crude		—

BRASS.

Solid Drawn Tubes	lb.	9¼d.
Brazed Tubes	,,	11¼d.
Rods Drawn	,,	8½d.
Wire	,,	7⅝d.
*Extruded Brass Bars	,,	4¼d.

COPPER.

Standard Cash		£31 10 0
Electrolytic		35 0 0
Best Selected		33 10 0
Tough		33 0 0
Sheets		64 0 0
Wire Bars		35 10 0
Ingot Bars		35 10 0
Solid Drawn Tubes	lb.	10d.
Brazed Tubes	,,	10d.

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0 3 3
‡Ferro Tungsten	,,	0 3 0
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.		
NOMINAL: 2–4% Carbon, scale 11/- per unit	ton	29 15 0
NOMINAL: 4–6% Carbon, scale 7/- per unit	,,	22 7 6
NOMINAL: 6–8% Carbon, scale 7/- per unit	,,	21 12 0
NOMINAL: 8–10% Carbon, scale 7/- per unit	,,	21 12 6
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/0 per unit	,,	32 17 6
Guar. max. 1% Carbon, scale 12/6 per unit	,,	36 17 6
§Guar. max. 0·7% Carbon, scale 12/6 per unit	,,	38 17 6
‡Manganese Metal 97-98% Mn.	lb.	0 1 2
‡Metallic Chromium	,,	0 2 5
§ Ferro-Vanadium 25–50%	,,	0 12 8
§ Spiegel, 18–20%	ton	7 10 0
Ferro Silicon—		
Basis 10%, scale 3/- per unit	ton	6 5 0
20/30% basis 25%, scale 3/6 per unit	,,	8 17 6
45/50% basis 45%, scale 5/- per unit	,,	13 10 0
70/80% basis 75%, scale 7/- per unit	,,	17 17 6
90/95% basis 90%, scale 10/- per unit	,,	28 17 6
§ Silico Manganese 65/75% Mn., basis 65% Mn.	,,	13 10 0
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0 0 4½
Ferro Phosphorus, 20–25%	ton	15 15 0
§ Ferro-Molybdenum, Molyte	lb.	0 4 6
§ Calcium Molybdate	,,	0 4 2

FUELS.

Foundry Coke—		
S. Wales	—	1 5 0
Scotland	—	1 8 0
Durham	0 19 0 to	1 2 0
Furnace Coke—		
Scotland	—	1 5 0
S. Wales	—	1 0 0
Durham	—	0 17 6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£55 0 0
*Commercial Ingots		41 0 0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0 0 9
*Cored Bars	,,	0 0 11

LEAD.

Soft Foreign	£13 16 0
English	15 2 0

MANUFACTURED IRON.

Scotland—	
Crown Bars, Best	£10 5 0
N.E. Coast—	
Rivets	10 10 0
Best Bars	10 2 6
Common Bars	9 5 0
Lancashire—	
Crown Bars	9 12 6
Hoops £10 10 0 to	12 0 0
Midlands—	
Crown Bars	9 12 6
Marked Bars	12 0 0
Unmarked Bars from	7 5 0
Nut and Bolt Bars £7 10 0 to	8 0 0
Gas Strip	10 12 6
S. Yorks—	
Best Bars	10 15 0
Hoops £10 10 0 to	12 0 0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	9d.
*Cored Bars	,,	11d.
†Strip	,,	10¾d.
†Sheet to 10 W.G.	,,	11d.
†Wire	,,	11⅞d.
†Rods	,,	11½d.
†Tubes	,,	1/1½
†Castings	,,	1/1

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—	
Hematite M/Nos.	£3 11 0
Foundry No. 1	3 12 6
,, No. 3	3 10 0
N.E. Coast—	
Hematite No. 1	3 8 0
Foundry No. 1	3 10 0
,, No. 3	3 7 6
,, No. 4	3 6 6
Silicon Iron	3 10 0
Forge	3 6 6
Midlands—	
N. Staffs Forge No. 4	3 7 0
,, Foundry No. 3	3 11 0
Northants—	
Foundry No. 1	3 10 6
Forge No. 4	3 2 6
Foundry No. 3	3 7 6
Derbyshire Forge	3 6 0
,, Foundry No. 1	3 14 0
,, Foundry No. 3	3 11 0
West Coast Hematite	3 7 0
East ,, ,,	3 8 0

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron Kr. 103	
Billets Kr. 240-310	£12 7 6–£16 0 0
Wire Rods Kr. 290-340	£15 0 0–£17 10 0
Rolled Bars (dead soft) Kr. 200-220	£10 6 0–£11 7 0
Rolled Charcoal Iron Bars Kr. 290	15 0 0

All per English ton. f.o.b. Gothenburg.
Converted at £1 = Kr. 19.40 approx.

SCRAP METAL.

Copper Clean	£27 0 0
,, Braziery	23 0 0
,, Wire	—
Brass	18 0 0
Gun Metal	25 0 0
Zinc	9 0 0
Aluminium Cuttings	66 0 0
Lead	12 0 0
Heavy Steel—	
S. Wales	2 15 6
Scotland	2 10 0
Cleveland	2 12 0
Cast Iron—	
Midlands	2 7 6
S. Wales	2 11 0
Cleveland	2 12 0
Steel Turnings—	
Cleveland	1 15 0
Midlands	1 14 0
Cast Iron Borings—	
Cleveland	1 5 0
Scotland	1 17 6

SPELTER.

G.O.B. Official	—
Hard	£11 12 6
English	15 2 6
India	13 0 0
Re-melted	14 7 6

STEEL.

Ship, Bridge, and Tank Plates	
Scotland	£8 15 0
North-East Coast	8 15 0
Midlands	8 17 6
Boiler Plates (Land), Scotland	8 10 0
,, ,, (Marine) ,,	—
,, ,, (Land), N.E. Coast	8 10 0
,, ,, (Marine) ,,	8 17 6
Angles, Scotland	8 7 6
,, North-East Coast	8 7 6
,, Midlands	8 7 6
Joists	8 15 0
Heavy Rails	8 10 0
Fishplates	12 10 0
Light Rails £8 10 0 to	8 15 0
Sheffield—	
Siemens Acid Billets	9 2 6
Hard Basic £6 17 6 to	7 2 6
Medium Basic £6 12 6 and	7 0 0
Soft Basic	5 10 0
Hoops £9 10 0 to	9 15 0
Manchester	
Hoops £9 0 0 to	10 0 0
Scotland, Sheets 24 B.G.	10 10 0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	2/-
Finished Bars 18% Tungsten	,,	2/9
Extras		
Round and Squares, ½ in. to ¼ in.	,,	3d.
Under ¼ in. to $\frac{3}{16}$ in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ⅜ in.	,,	3d.
,, ,, ½ in. × ¼ in.	,,	1/-

TIN.

Standard Cash	£226 10 0
English	226 15 0
Australian	—
Eastern	227 15 0
Tin Plates I.C. 20 × 14 box	18/2

ZINC.

English Sheets	£23 0 0
Rods	29 10 0
Battery Plates	—
Boiler Plates	—

*McKechnie Brothers, Ltd. June 11. † C. Clifford & Son, Ltd., June 11. ‡ Murex Limited, June 11.

Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.

§ Prices ex warehouse, June 11.